EVALUATION OF FISH RESOURCES OF THE MACKENZIE RIVER VALLEY

VOLUME I

1973

AN EVALUATION OF THE FISH RESOURCES OF THE MACKENZIE RIVER VALLEY AS RELATED TO PIPELINE DEVELOPMENT

Volume I

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Les données de ce rapport sont le fruit de recherches menées dans le cadre du programme écologique et social des pipelines du Nord, par le groupe fédéral de travail affecté à l'exploitation du pétrole dans le Nord.

1. SUMMARY

In May of 1972, the Department of the Environment, Fisheries Service, began the second year of a proposed four year investigation into possible effects of northern pipeline construction on the fish resources of the Mackenzie River valley. In addition to base camps established at Arctic Red River, Norman Wells and Fort Simpson during the 1971 program, an additional base was located at Aklavik in 1972. Field camps were also set up in Fort McPherson and on the Rat and Rabbitskin rivers. A synoptic helicopter survey was again made into those areas beyond the reach of river bases.

Sampling stations were located on much of the Mackenzie River and most main stem tributaries. Fish were collected with gill nets, seines, trap nets and by angling. A tagging program was operated from each base during 1972 and included all large fish species.

Fish species composition, length-weight relationships, age and growth characteristics and food habits of the more abundant species were determined to provide an index of relative species sensitivity. Migration routes and times, spawning characteristics, spawning and nursery areas are being investigated as are domestic fishery requirements.

A stream catalogue containing fisheries information, chemical and physical characteristics of major tributaries has been completed. Also included are engineering evaluations of stream bank stabilities.

To date, 34 species of fish have been encountered in the Mackenzie River system. Of these, Arctic char, lake trout, inconnu, humpback and broad whitefish, Arctic and least cisco, walleye and Arctic grayling appear to be the species which could be most affected by construction of northern pipelines. Numbers and distributions vary with the individual species as does relative sensitivity.

Siltation or removal of spawning gravel, blocking of fish migrations, destruction of rearing areas, or chemical contamination of the aquatic environment from spills, are possible adverse effects from northern pipeline construction activities.

In the opinion of the Fisheries Service, the Mackenzie River delta, Big Fish River, Rat River, Jean-Marie Creek and the Trout River are systems which, due to the sensitivity of the resource or its importance to the domestic fishery, should be avoided by any pipeline routing. Should avoidance be deemed impossible, restriction on construction techniques and scheduling will be required if the resource is to be adequately protected. Additional streams are listed which, pending further investigation, may be included in this sensitivity list.

May 15 to June 30, and September 15 to November 15 are times during which the fish resource is considered biologically sensitive to northern pipeline construction. Spawning and migrations of major fish species occur during these periods, and stream disturbance at such times should be kept to a minimum.

Specific safeguards for protection of the resource and the domestic fishery during pipeline construction and operation are provided. Primarily they are aimed at ensuring that undue silt loads or chemical pollutants do not enter the aquatic environment, and that fish migrations and the domestic fishery are not interfered with.

As pipeline routes are defined, recommendations will be made for protection of the resource on an individual stream basis. A more intensive tagging program is planned for 1973 in an effort to better define migration routes and population sizes. Representative tributaries in each base area will be studied intensively to fill existing knowledge gaps in the life histories of major species.

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4. INTRODUCTION

Pipeline construction can result in complicated and often long term effects on an aquatic environment and particularly on fish. Construction of a Mackenzie valley pipeline poses a severe threat to fish because of the relative sensitivity of the Arctic and sub-Arctic environments, as well as many of the fish stocks. Detailed biological data are vital if realistic recommendations are to be proposed for protection of the resource both during and after pipeline construction.

Pipeline activities in or near the aquatic environment can adversely affect the fish resource in a variety of ways. The greatest concerns are the possibilities of blocking fish migrations, removal or siltation of spawning gravel, and destruction of vital habitat resulting from increased siltation, chemical or oil pollution. Effects of construction on migrating populations can be minimized through route choice and construction scheduling, provided data is available on migration routes and times, spawning and nursery areas and general life histories. Studies of age composition and growth provide an indication as to the possible sensitivity of fish populations to environmental disturbance. Food habit studies determine major food items of fish species, thus providing an estimate of effect should food organisms be destroyed.

In May, 1971, the Department of the Environment, Fisheries Service, began a four year investigation into the fish resources of the Mackenzie River valley. Results of the first year's study were presented in two volumes (Hatfield et al., 1972). Volume I provided preliminary data on species distribution, relative abundance, general life history and growth, and tentative recommendations for protection of the resource. Volume II of the report presented details on methods, results and a stream catalogue.

This report encompasses the second year of the study, the primary objectives of which were to refine and add to the life history data collected during 1971, with particular emphasis on migration routes and spawning habits. Significant differences from the 1971 program

included a major fish tagging study, and the addition of a base camp at Aklavik to study the biologically rich Mackenzie delta area. Field camps were established in Fort McPherson to monitor the substantial domestic fishery on the Peel River system, and on the Rat and Rabbitskin rivers to intensively study the resources of two typical Mackenzie tributaries.

Volume I of this report outlines those aspects of the resource which, in the opinion of the Fisheries Service, will be most immediately and seriously affected by pipeline construction. Volume II consists of an updated stream catalogue, including an engineering evaluation of stream bank stabilities.

It should not be construed that parameters such as food habits and growth rates will not be adversely affected by construction activities. Although such changes are often not readily obvious, their impact on a fish population can be drastic. Reference is made to these factors in this report, but in the interests of brevity, detailed data are presented in two additional reports. The first of these, Fish Resources of the Mackenzie River Valley, Interim Report II, 1973, includes detailed information on methods, results and the biology of Mackenzie River fish species. The second, Fish Resources of the Mackenzie River Valley, Special Report, An Intensive Study of the Fish Resources of Two Main Stem Tributaries, presents results obtained from intensive surveys conducted on the Rabbitskin and Rat rivers.

5. RESUME OF CURRENT STATE OF KNOWLEDGE

Early records of the fish resources of northern Canada consist mostly of the field notes of Mackenzie, Hearne, Tyrrell, Franklin and others. It was not until 1888 that the Canadian government made an attempt "to inquire into the resources of the great Mackenzie Basin" (Mair and McFarlane, 1907). However, only passing reference was made to fish in this report, and, from 1888 to the present, only a meagre amount of additional information has been collected in missionaries' diaries, R.C.M.P. catch records and in the memories of local people.

With the exception of recent pipeline oriented reports concerning the fish resources of the Mackenzie area, very little specific information has been published. A notable exception is the book by McPhail and Lindsey (1970) which summarized what was then known on the taxonomy, life history, and distribution of fish in northwestern Canada and Alaska. The authors pointed out, however, that "Areas in which the fish fauna is virtually unknown are the northern Yukon Territory (north of Dawson City), the middle Mackenzie River system (from Fort Providence to Arctic Red River and the entire districts of Keewatin and Franklin".

6. STUDY AREAS

It is physically impossible to construct a major pipeline in northern Canada without disrupting the aquatic environment. Although such disruptions will adversely affect fish resources, the lack of biological data makes it difficult to forecast with any degree of certainty the magnitude of these effects. A considerable volume of information presently exists on several northern fish species whose ranges include southern regions of Canada. However, it is frequently difficult to relate this information to Arctic fish populations.

Aspects of the resource studied under the present program include distribution, food habits, age and growth, life history including spawning and nursery areas, and migratory characteristics. It is impossible to examine in any detail, the fish resources of each stream crossed by proposed pipeline routes. However, with the data obtained from study areas, probable effects of pipeline crossings on the fish resources of most Mackenzie River tributaries can be predicted.

It is expected that the biological data collected on Mackenzie valley fish will be applicable to the same species in other areas of the Northwest Territories. However, variation will result due to such factors as differences in types of habitat, water chemistry and productivity rates. Considerable care must be taken in extrapolating results beyond the Mackenzie valley.

7. METHODS

7.1 Description of the Area

The Mackenzie River flows northward from Great Slave Lake to the Arctic Ocean and has headwaters in the Yukon Territory, northern British Columbia, Alberta and Saskatchewan (Fig. 7). Greatest total distance from headwater to the Arctic Ocean is 4,321 km (2,685 miles). The Mackenzie is navigable by river tugs and barges during the ice-free period from mid-June to mid-October, and is the primary supply route for all towns from Fort Simpson downstream to Inuvik. The river is characterized by a heavy silt load particularly north of Fort Simpson where the Liard River enters from northern British Columbia. Numerous tributaries enter the Mackenzie River system. However, many of these are seasonal streams which have peak discharge in late May or early June, and dry up over the summer, or freeze to the bottom during winter. Only 12 to 15 watersheds contribute significantly to the total flow of the river. A complex system of channels, islands, lakes and muskeg comprise the delta which is some 19,782 sq km (7,635 sq miles) in area (Fig. 1).

Fig. 1. The Mackenzie River Delta

In winter, ice up to 2.4 m (8 ft) thick covers the main stem of the Mackenzie River. During spring run-off, the river may increase 3.0-6.1 m (10-20 ft) in depth. Throughout the summer, heavy rains in the mountains may result in a 1.5 m (5 ft) increase in water depth in both tributaries and the Mackenzie River. During peak discharges, there are large quantities of drifting debris.

Substantial domestic fisheries exist throughout the river system, particularly around tributary mouths near settlements, and in the Mackenzie delta. Much of the catch is taken during or immediately following freeze-up and breakup when the major fish runs occur.

Permafrost is continuous from Arctic Red River north and discontinuous but widespread to Fort Simpson in the south. Boreal forest lines the river to the Arctic Ocean. More information on river conditions and geology of the area may be found in Mackay (1963).

7.2 Sampling Locations

In addition to the three river bases, Arctic Red River, Norman Wells and Fort Simpson, established in 1971 (Hatfield et al., 1972. Vol. I), bases were also set up at Aklavik and Fort McPherson in 1972 (Fig. 7). Aklavik is centrally located for detailed biological study of the complex Mackenzie delta area. Fort McPherson gave access to a study of the Peel River system, which supports significant runs of broad whitefish, Arctic cisco, least cisco, and inconnu (Hatfield et al., 1972. Vol. II) (A list of generic nomenclature associated with the common fish names used in this report appears in the appendix).

An effort was made in each study area to select index sample locations that would give a representative sample of all fish species and an indication of migratory routes and nursery areas. Index locations are shown in Fish Resources of the Mackenzie River Valley, Interim Report II, 1973). However, river conditions frequently restricted the selection of locations to back eddies and to the confluence of tributaries. Locations sampled in 1971 were generally utilized in 1972 as index sample locations.

In the Arctic Red River study area, an intensive stream survey was undertaken on the Rat River (Fig. 7). A similar study was conducted on the Rabbitskin River (Fig. 7) in the Fort Simpson study area. Results of both intensive stream studies are presented in a separate report: Fish Resources of the Mackenzie River Valley, Special Report, An Intensive Study of the Fish Resources of Two Main Stem Tributaries.

Since many major tributaries were beyond easy access from base camps, a synoptic helicopter survey was conducted in 1971 and 1972 to assess the fish resources of these streams. The survey conducted in 1972 maintained for the most part the sample locations established in 1971 (Hatfield et al., 1972. Vol. II). With the inclusion of the Aklavik base, the survey was extended to include west side

tributaries of the Mackenzie delta area and a number of delta lakes. A more intensive survey of the Great Bear River was undertaken in late September and early October. On most tributaries, the gill net locations were primarily at or near stream outlets; seining locations were upstream. An engineering evaluation of river bank stability was also conducted on most major tributaries during June and July. A detailed account of synoptic methods and results is presented in a separate report: An Evaluation of the Fish Resources of the Mackenzie River Valley as Related to Pipeline Development, Volume II, 1973.

7.3 Sampling Techniques and Catch Analysis

Sampling techniques and catch analysis were similar for all bases. However, variations occurred due to changing river conditions.

7.3.1 Netting Crews

Sampling began shortly after break-up (late May-June) and ended by mid-November.

In sampling gill net locations, on a two week cycle basis, three 22.9 m (25 yard) sections of 3.8, 7.6 and 12.7 cm (1½, 3, 5 inch) meshes were alternated with similar sections of 5.1, 10.2 and 14.0 cm (2, 4, 5½ inch) meshes. The three sections were either joined to form a 68.6 m (75 yard) gang or fished separately (Fig. 2). Nets were usually fished for 18 to 24 hr.

Seining locations were also sampled by two week cycles using 9.1 or 18.3 m (30 or 60 ft) beach seines of 0.3 or 0.6 cm (1/8 or 1/4 inch) mesh (Fig. 3).

Gill net caught fish were sampled for weight (g), fork length (mm), sex and maturity. Scale and otolith samples were taken for age determinations. (Otoliths are small ear bones located in the brain cavity). Where possible, 15 stomach samples, from those species listed in Table 1, were collected per cycle by each river base crew. Large catches were subsampled for similar data.

Small fish in seine catches were preserved and sent to the Fisheries Service laboratory, Winnipeg, for analysis. Larger fish were sampled in the same manner as those taken in gill nets.

Frequently, live fish from both gill net and seine catches were tagged.

Fig. 2. Retrieving a gill net from a tributary of the Mackenzie River

Fig. 3. Seining a tributary of the Mackenzie River

Table 1. Size groups from which stomach samples were collected.

Species	Size Group (mm)		
Arctic cisco	0-100	100-300	300 plus
Arctic grayling	0-100	100-200	200 plus
Broad whitefish	0-100	100-200	200 plus
Inconnu	0-100	100-400	400 plus
Least cisco	0-100	100-200	200 plus
Northern pike	0-100	100-400	400 plus
Yellow walleye	0-100	100-200	200 plus
Flathead chub	Small Subsample		
Longnose sucker	Small Subsample		
White sucker	Small Subsample		

7.3.2 Tagging Crews

At each base, fish were collected for tagging purposes utilizing gill nets, trap nets (Fig. 4) and beach seines. In an effort to tag and recapture a representative number of fish, tagging locations were distributed throughout each study area. Tagging effort was most intensive at locations where fish concentrations occurred.

Fish with length greater than 15 cm (6 inches) were tagged at the posterior base of the dorsal fin. Tags consisted of coded vinyl tubing and were inserted by means of a tagging gun (Fig. 5). Fork length and a small scale sample were taken from all tagged fish. Tagged fish were held in a holding pen for 15 to 30 minutes, and, if swimming

Fig. 4. A trap net, used to capture live fish for tagging

Fig. 5. Applying a numbered tag to an inconnu from the Mackenzie River

normally, were released. Complete data were taken from all fish that were not tagged and released. Recaptured fish, taken by study crews, were released if considered to be in good condition. Otherwise, they were completely sampled. A one dollar reward was offered for each tag returned by anglers or domestic fishermen. Posters, giving instructions for returning tags, were placed in most Mackenzie River settlements.

7.3.3 Intensive Stream Survey

Intensive stream survey crews utilized gill nets, seines, drift nets, angling and visual observations to determine relative abundance, spawning areas, nursery areas and general life history of fish species in the Rat and Rabbitskin rivers. Live fish caught were tagged using the techniques employed by the tagging crew (7.3.2). Other fish were completely analysed in the field or in the laboratory.

7.3.4 Synoptic Survey

The synoptic crew made two surveys of the Mackenzie River system. The first survey began on May 2 at Fort Simpson and working north, terminated July 13 in Aklavik. The second survey began August 25 in Aklavik and working south, terminated at Norman Wells by mid-October.

Fishing gear consisted of seines and gill nets. Sampling methods were similar to those used by the netting crews with the exceptions that stomach contents were analysed in situ and otoliths were not taken.

7.3.5 Domestic Catch Analysis

Statistics were collected on domestic fishery catches in the Fort

McPherson area from July 12 to August 31, 1972. Of 24 camps checked, 20 were located along the Peel River from its mouth to 120.7 km (75 miles) upstream; four were on the Husky Channel near its junction with the Peel River. Some camps were active from breakup in June until after freeze-up in October. Most ceased operations in early September. Fishing (exclusively gill nets) was continuous and nets were lifted at least once each day.

Daily catches were recorded at three camps on the Peel River and one on the Husky Channel. Catches for the remaining camps were tabulated by counting all fish stored in the camp at the end of the study period (Fig. 6).

Additional sampling and tagging was done by Fisheries staff using gill nets and seines.

Fig. 6. Drying a domestic catch of whitefish.

7.4 Laboratory Analysis

Seine catches were identified using taxonomic keys available in Faber (1970), Mansueti and Hardy (1967) and McPhail and Lindsey (1970). Most specimens were keyed to species; however, many larval fishes of the coregonid, salmonid and catostomid families could only be keyed to genus. A number of specimens were sent to the Canadian National Museum of Natural Science for identification and verification. Subsamples of each species were analysed for fork length, weight, age and stomach contents.

From each base, 3 fish of each species from each 10 mm length interval were aged from scales. Length-age relationships were determined and used as an indication of the growth rates of individual species.

Stomach contents from a subsample of each species were examined. Identifications, numerical counts and volumetric measurements of food items were made.

7.5 Data Analysis

7.5.1 Computer Analysis

Data collected in the field were coded and later analysed by computer. Information retrieved from the computer included species distribution, per cent species composition, sex ratios, catch per unit effort, length frequencies, and length-weight relationships.

7.5.2 Tag Return Analysis

Tag returns from field crews, sport and domestic fishermen, were combined to describe fish movements and migration routes. Where a significant number of tags were returned, the Peterson Method was used to estimate the approximate population size.

Estimates of the population of northern pike in the Fort Simpson study area were calculated at the end of each cycle by a Schnabel type formula (Lagler, 1952).

7.5.3 Synoptic Map Interpretations

Stream maps were reproduced from topographic maps of 1:250,000 scale. Stream lengths were measured with a map measurer, while drainage areas were obtained with a polar compensating planimeter.

8. RESULTS

8.1 Species Distribution

The distribution of fish species caught by base and synoptic crews in 1971 and 1972 is presented in figures 8 to 35. Figure 7 includes the names of all tributaries which have been indicated on individual distribution maps, as well as base camp locations.

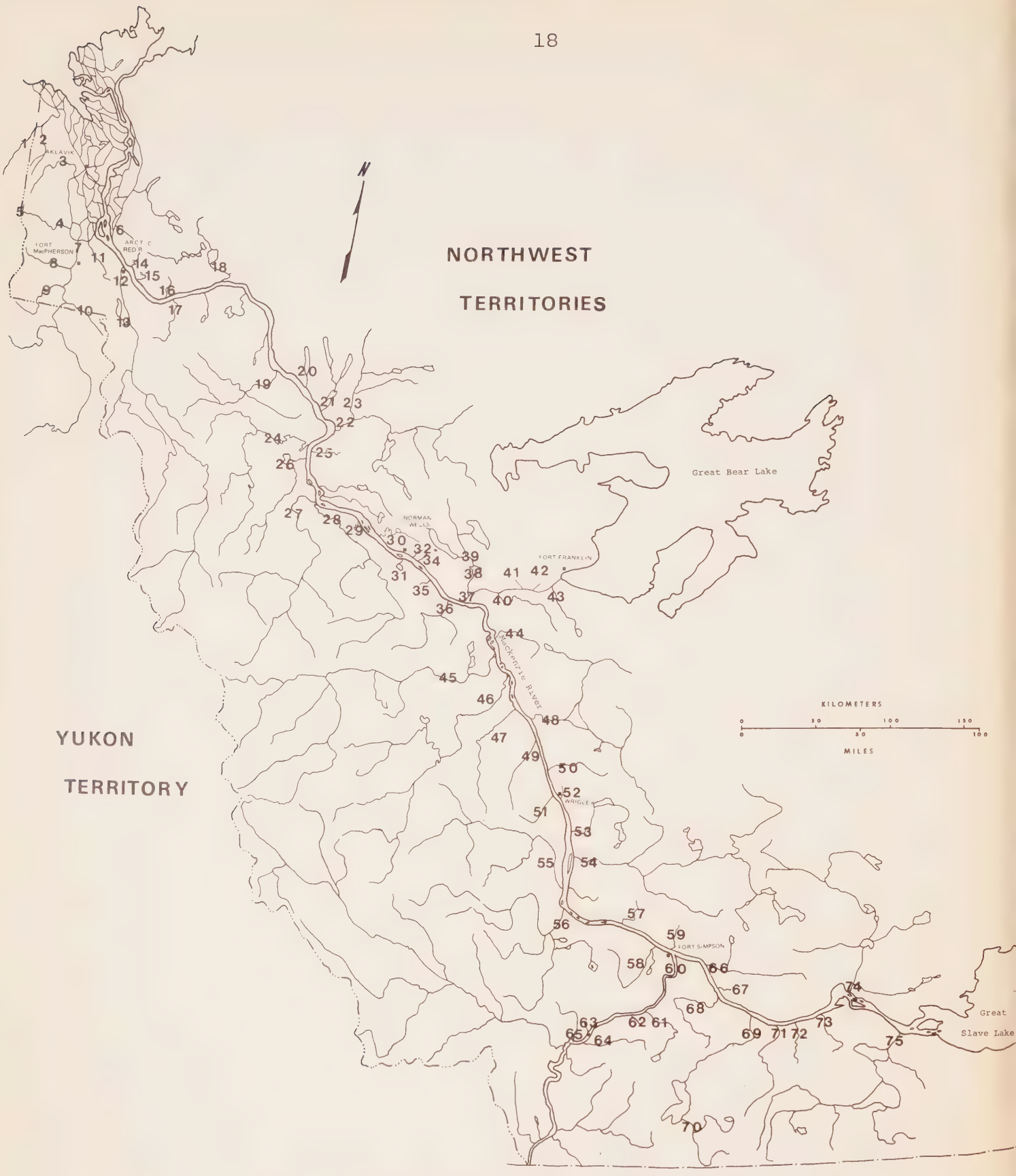

Fig. 7. Map of the Mackenzie River system and base camps.

LEGEND

1. Big Fish River
2. Cache Creek
3. Willow River
4. Rat River
5. Fish Creek
6. Rengleng River
7. Peel River
8. Stony Creek
9. Vittrekwa River
10. Satah River
11. Frog Creek
12. Arctic Red River
13. Swan Creek
14. Tsital Trein Creek
15. Pierre Creek
16. Rabbit Hay River
17. Tree River
18. Travaillant River
19. Ontaratue River
20. Tieda River - Yeltea Lake
21. Loon River
22. Hare Indian River
23. Bluefish River
24. Ramparts River
25. Tsintu River
26. Hume River
27. Mountain River
28. Carcajou River
29. Trapper Creek
30. Oscar Creek
31. Stewart Creek
32. Canyon Creek
33. Prohibition Creek
34. Vermilion Creek
35. Slater Creek
36. Little Bear River
37. Great Bear River
38. Brackett River
39. Loche River
40. St. Charles Creek
41. Wolverine Creek
42. Stick Creek
43. Porcupine River
44. Big Smith Creek
45. Keele River
46. Redstone River
47. Dahadinni River
48. Blackwater River
49. Johnson River
50. Ochre River
51. Wrigley River
52. Hodgson Creek
53. River between two Mountains
54. Willowlake River
55. Root River
56. North Nahanni River
57. Trail River
58. Martin River
59. Harris River
60. Liard River
61. Poplar River
62. Birch River
63. Matou River
64. Blackstone River
65. Grainger River
66. Rabbitskin River
67. Spence River
68. Jean-Marie Creek
69. Trout River
70. Island River
71. Redknife River
72. Bouvier River
74. Horn River
75. Kakisa River

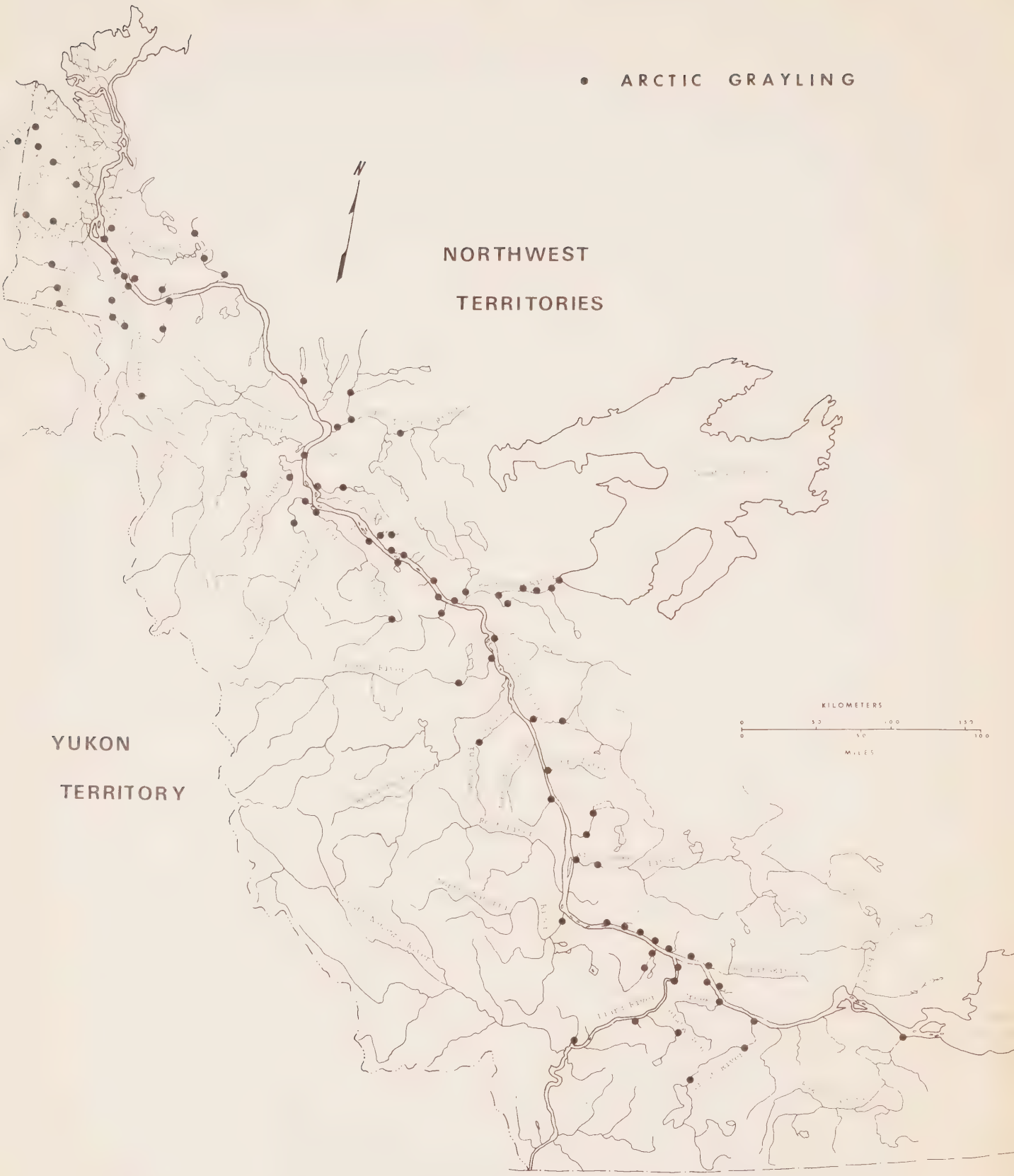

Fig. 8. Distribution of Arctic grayling, Thymallus arcticus (Pallas), in the Mackenzie River study, 1971 and 1972.

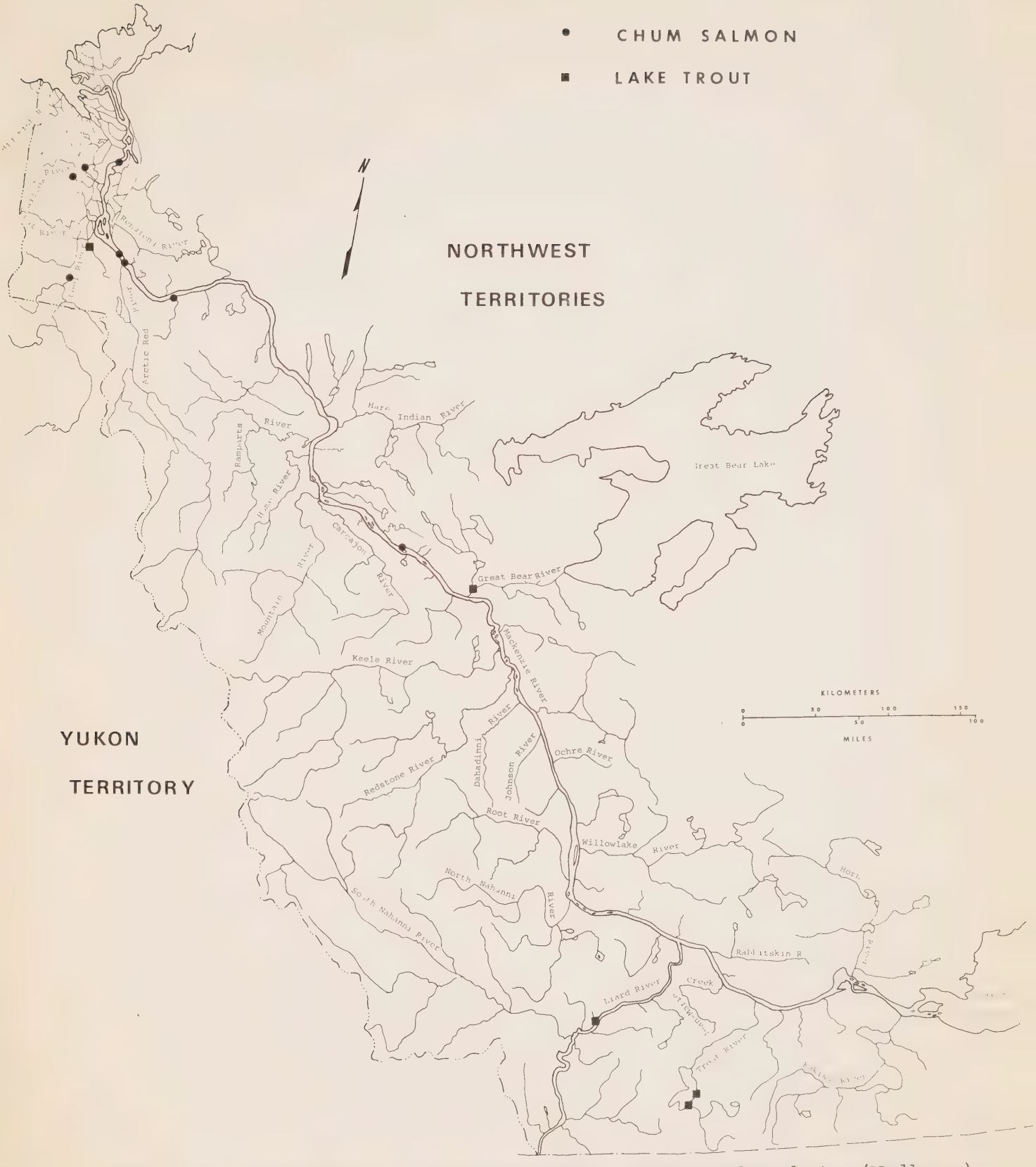

Fig. 9. Distribution of chum salmon, Oncorhynchus keta (Walbaum), and lake trout, Salvelinus namaycush (Walbaum), in the Mackenzie River study, 1971 and 1972.

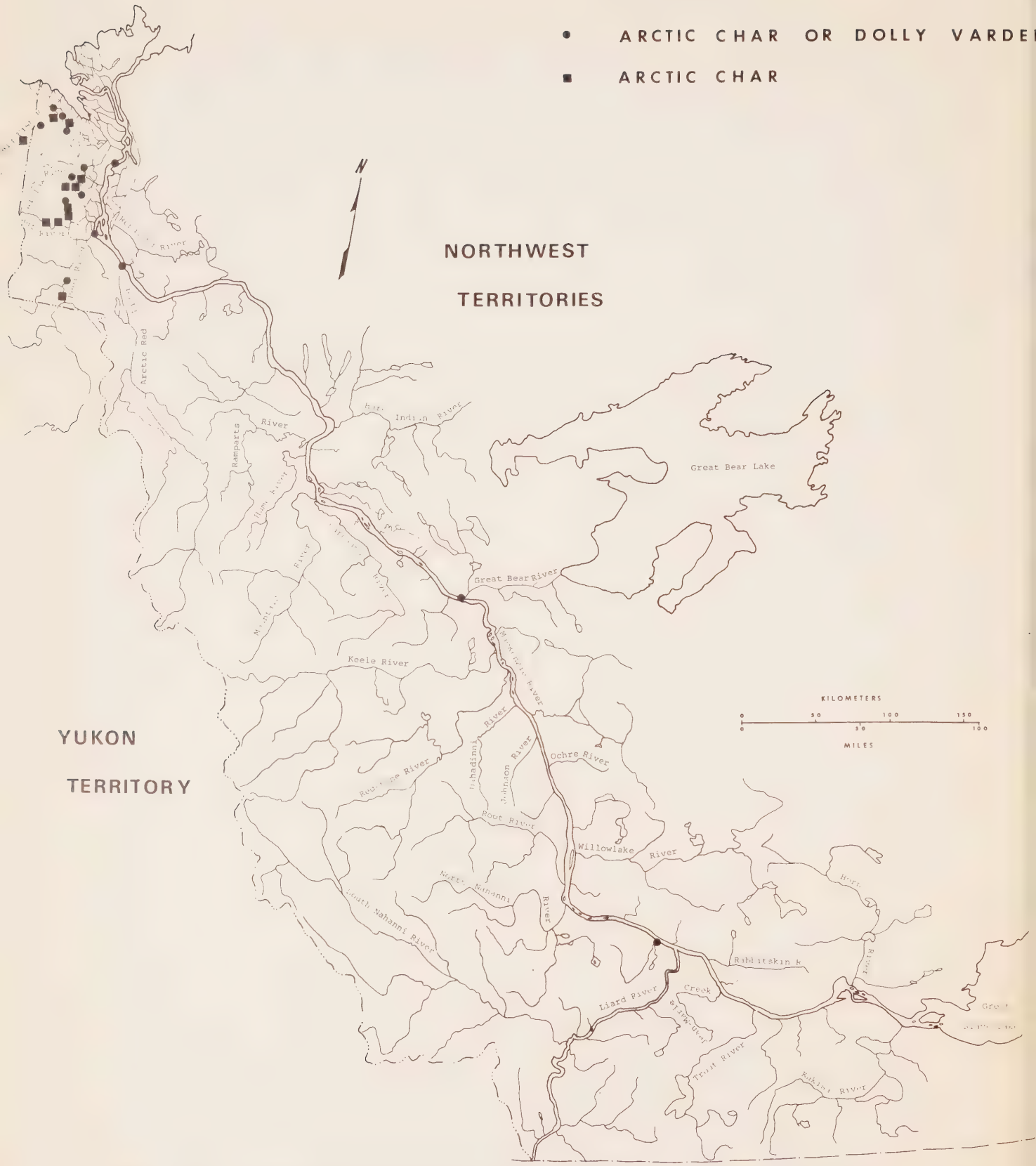

Fig. 10. Distribution of Arctic char, S. alpinus (Linnaeus), and Arctic char - Dolly Varden, S. malma (Walbaum), complex, in the Mackenzie River study, 1971 and 1972.

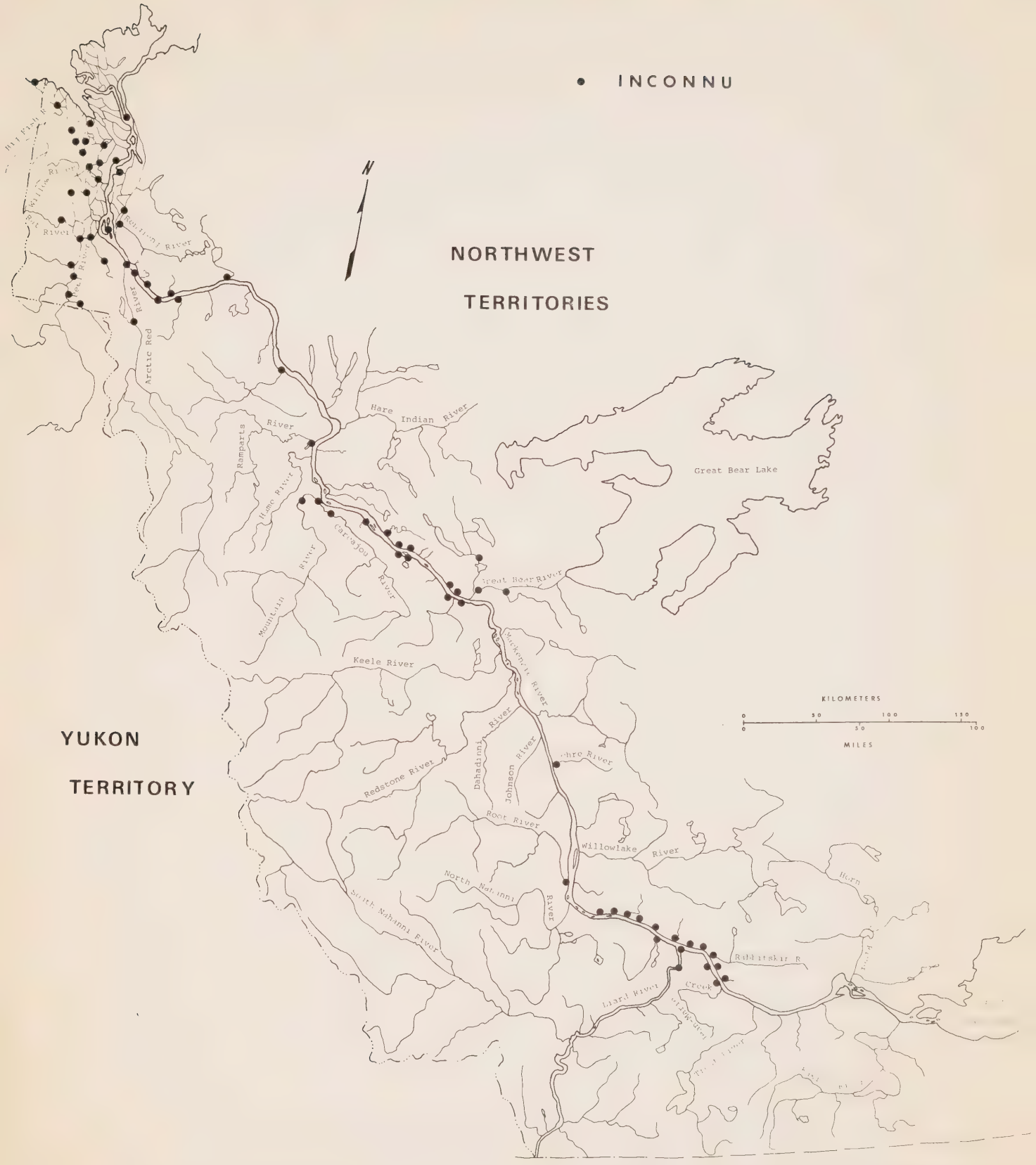

Fig. 11. Distribution of inconnu, Stenodus leucichthys nelma (Pallas), in the Mackenzie River study, 1971 and 1972.

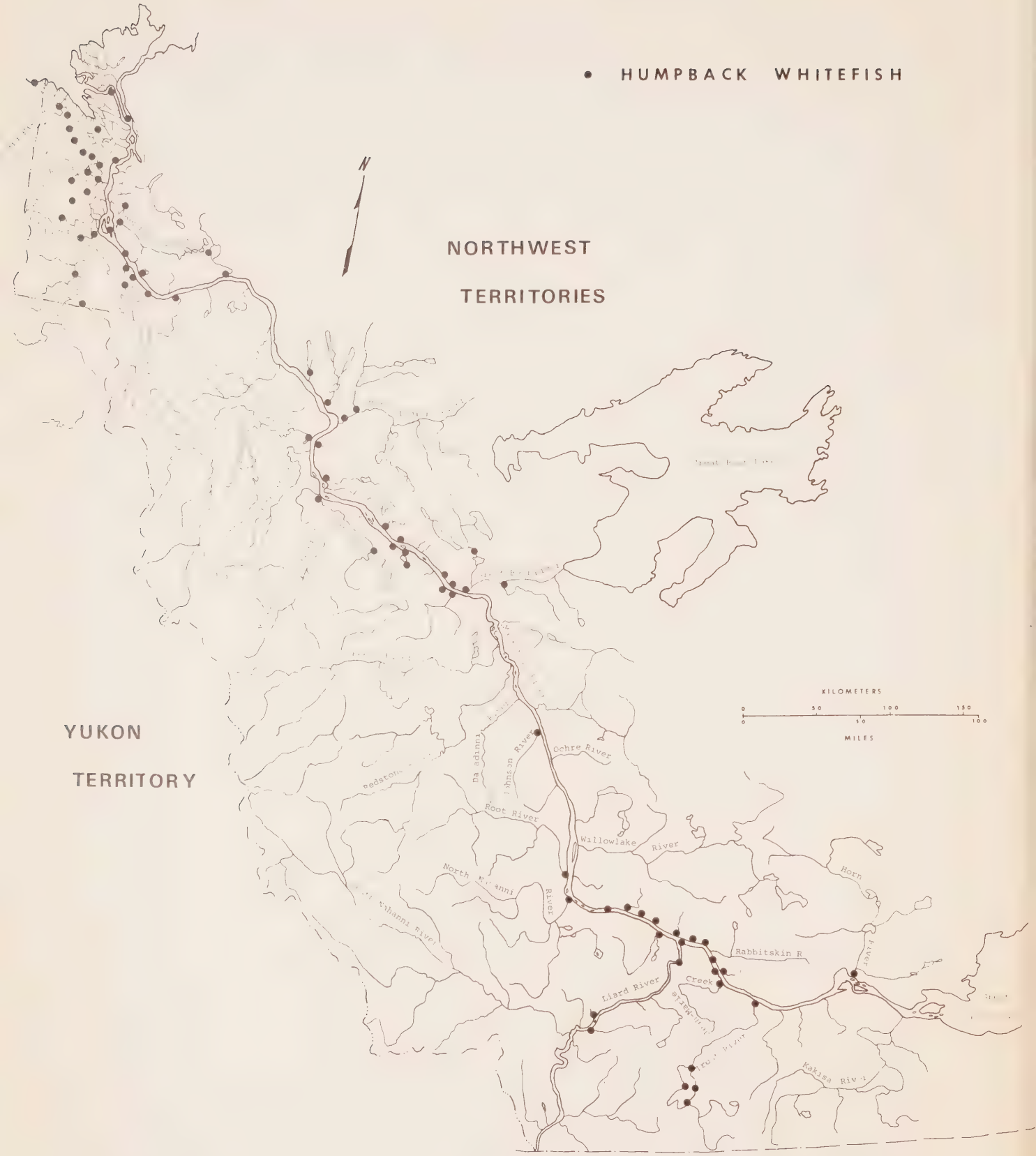

Fig. 12. Distribution of humpback whitefish, Coregonus clupeaformis (Mitchill), in the Mackenzie River study, 1971 and 1972.

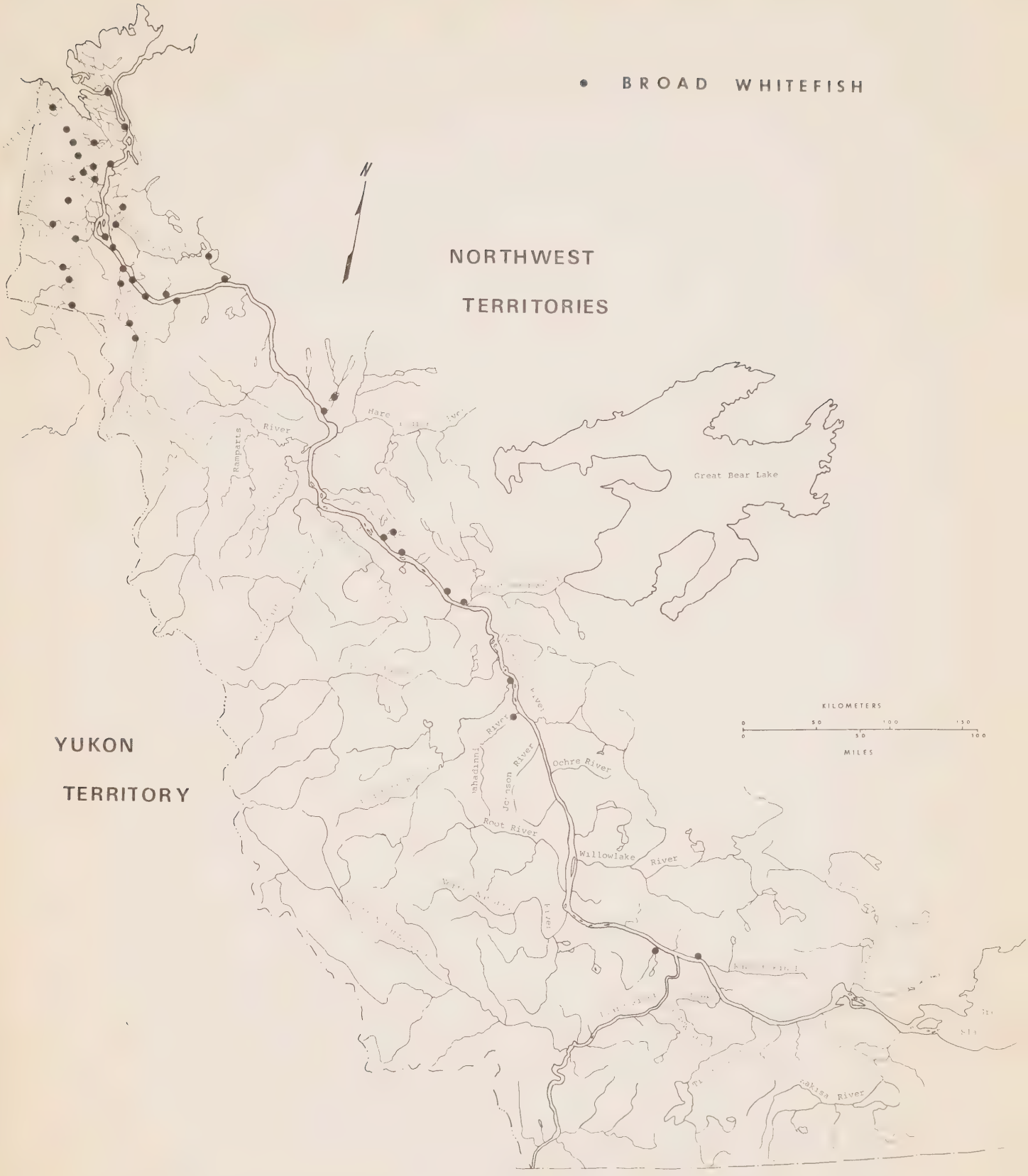

Fig. 13. Distribution of broad whitefish, C. nasus (Pallas), in the Mackenzie River study, 1971 and 1972.

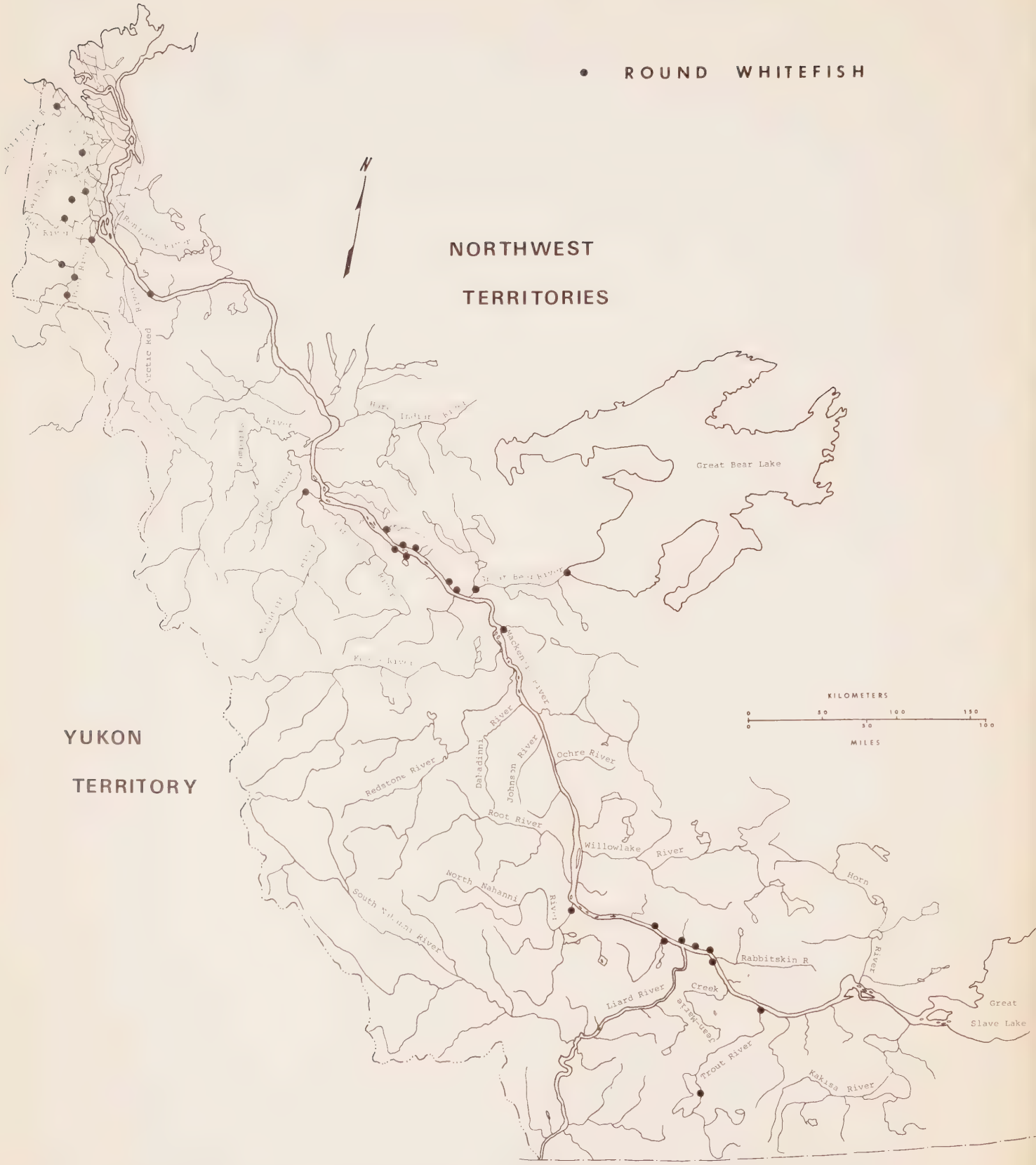

Fig. 14. Distribution of round whitefish, Prosopium cylindraceum (Pallas), in the Mackenzie River study, 1971 and 1972.

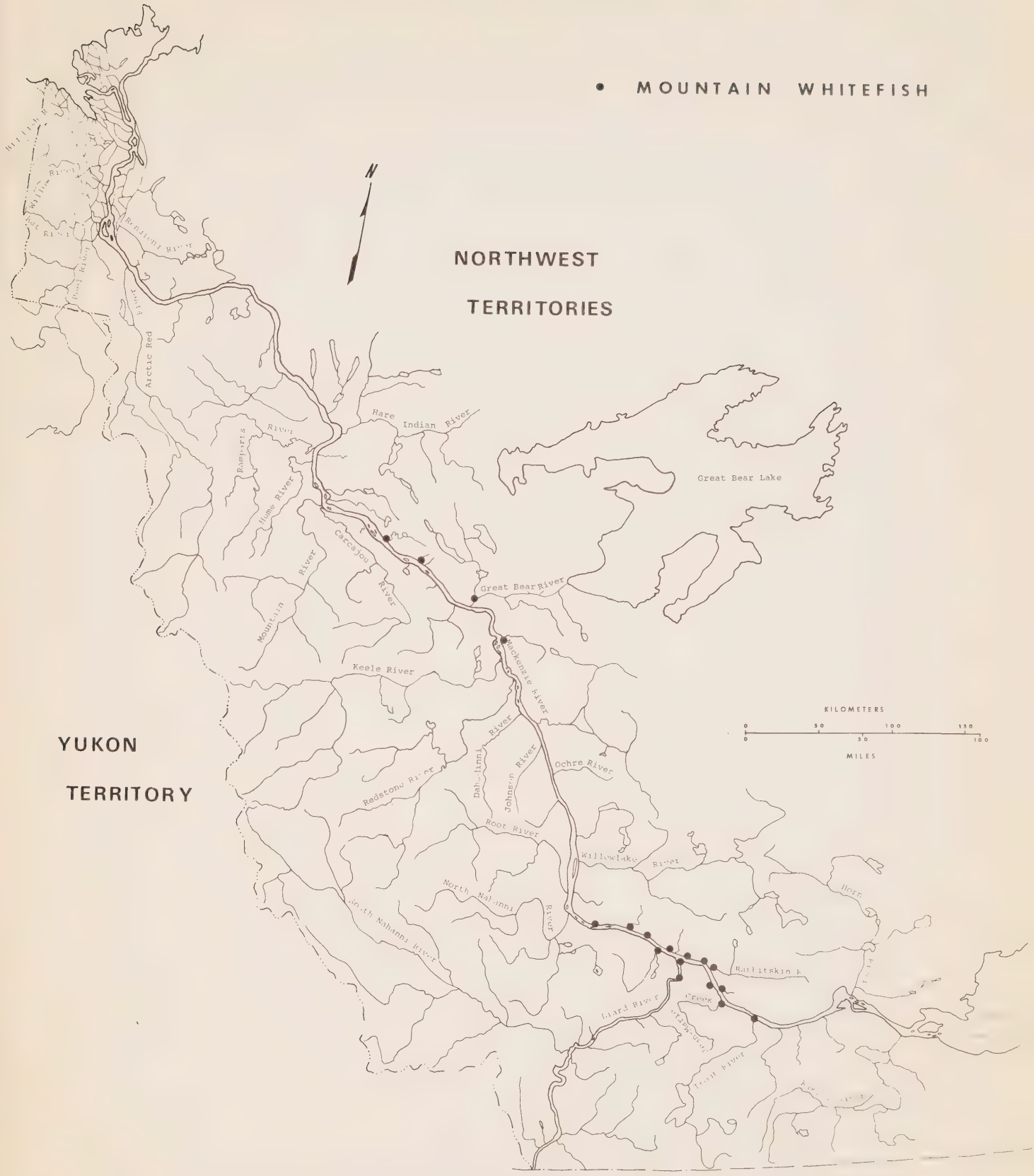

Fig. 15. Distribution of mountain whitefish, P. williamsoni (Girard), in the Mackenzie River study, 1971 and 1972.

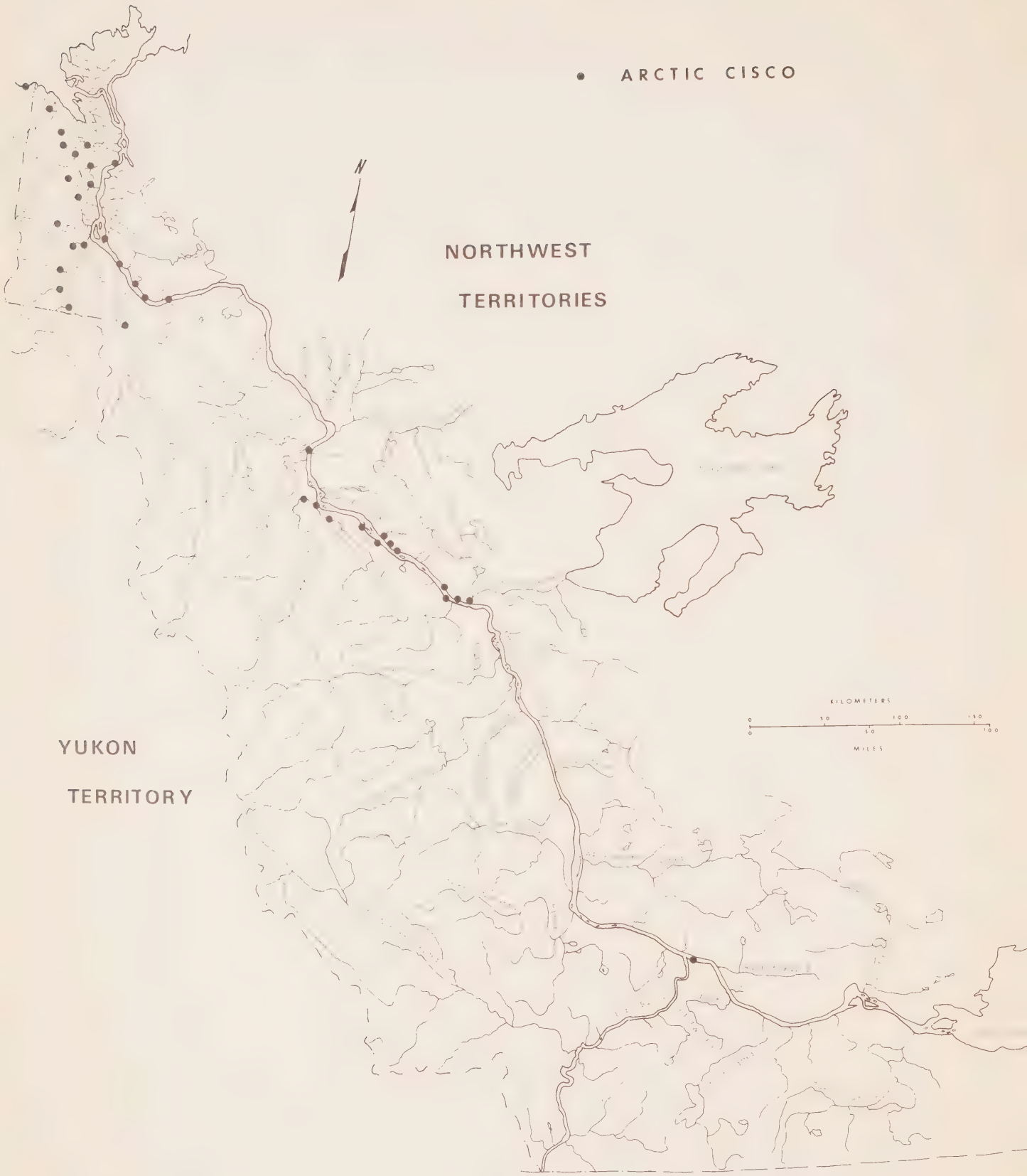

Fig. 16. Distribution of Arctic cisco, C. autumnalis (Pallas), in the Mackenzie River study, 1971 and 1972.

Fig. 17. Distribution of least cisco, C. sardinella (Valenciennes), in the Mackenzie River study, 1971 and 1972.

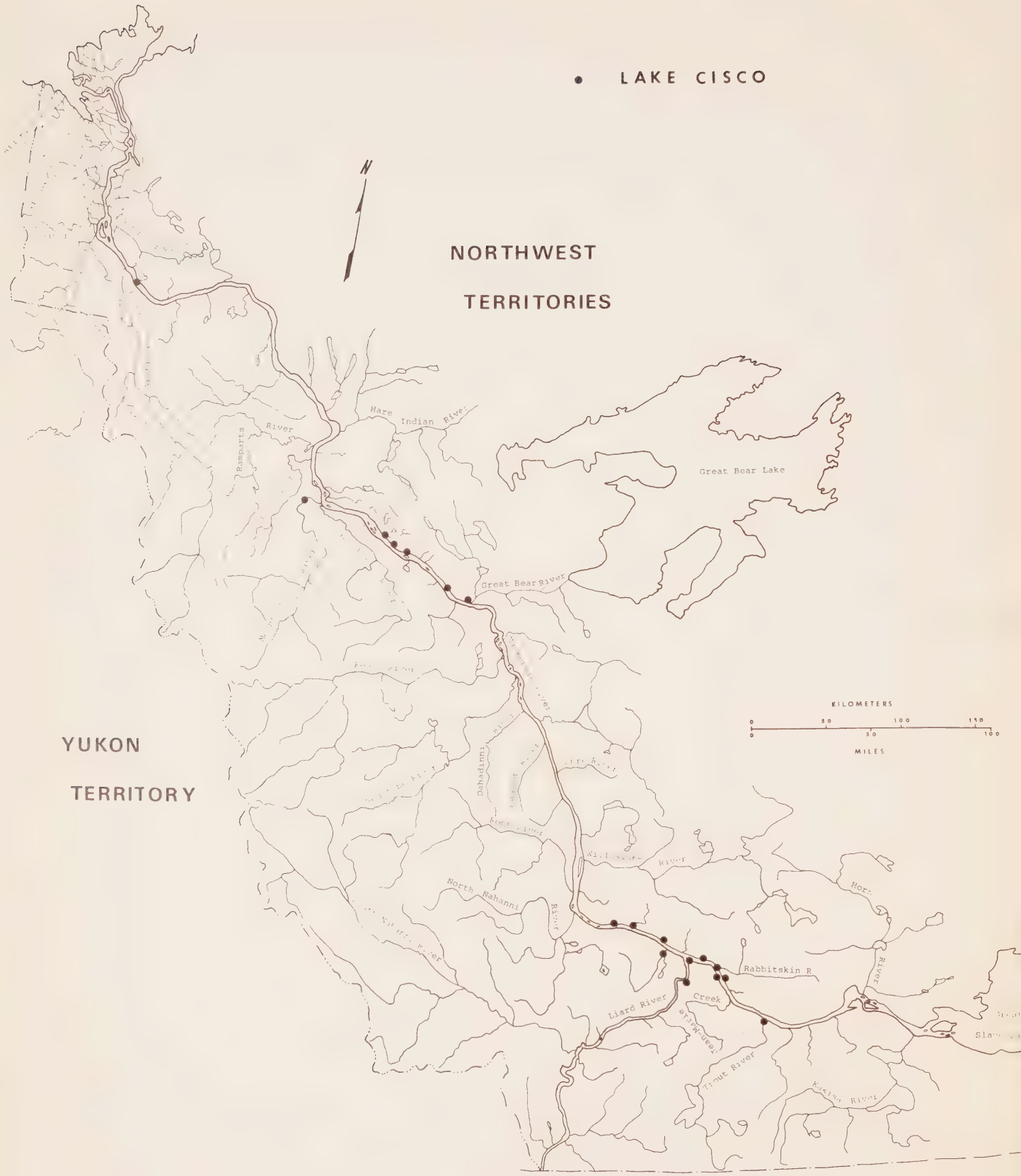

Fig. 18. Distribution of lake cisco, C. artedii (LeSueur), in the Mackenzie River study, 1971 and 1972.

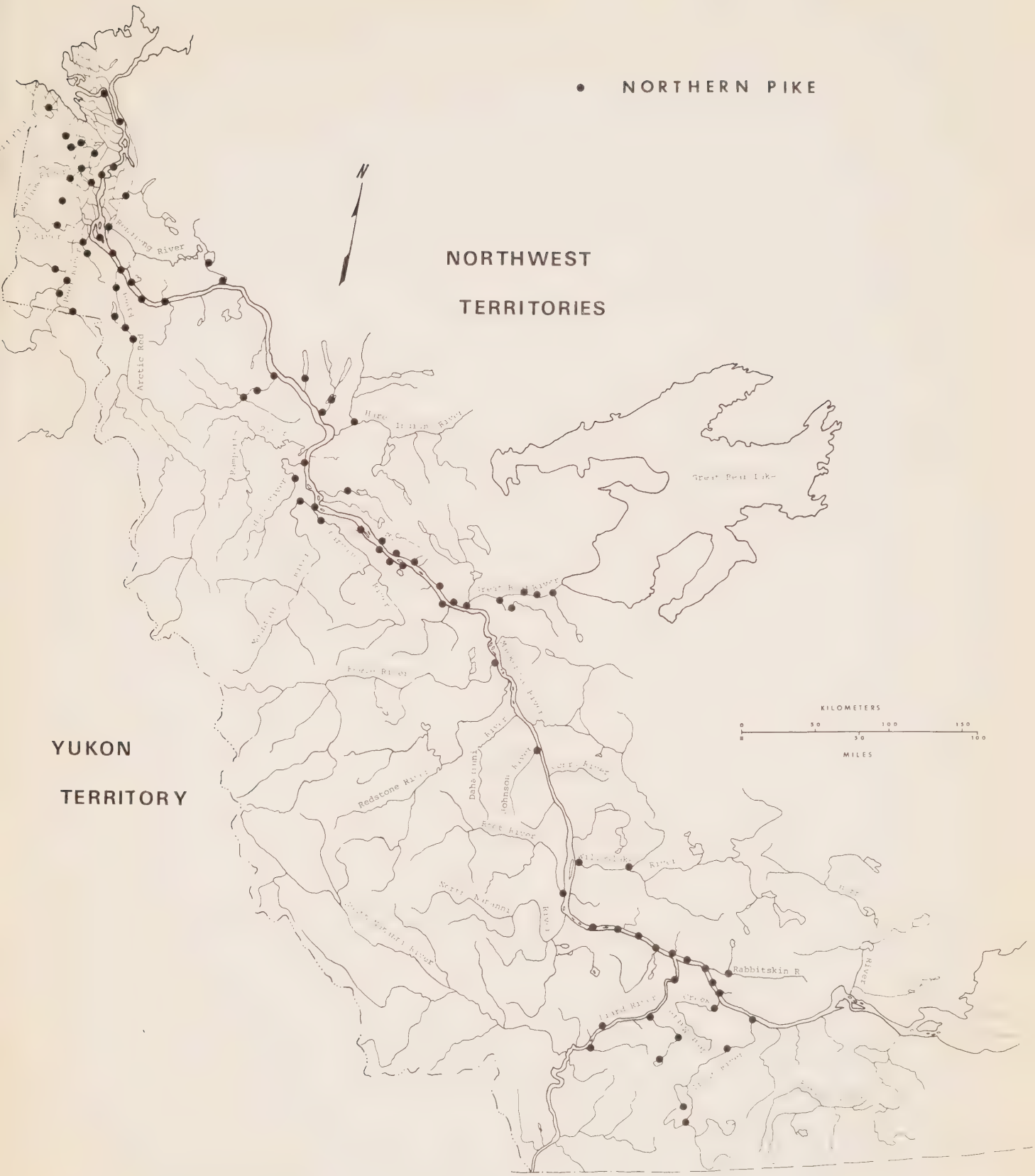

Fig. 19. Distribution of northern pike, Esox lucius (Linnaeus), in the Mackenzie River study, 1971 and 1972.

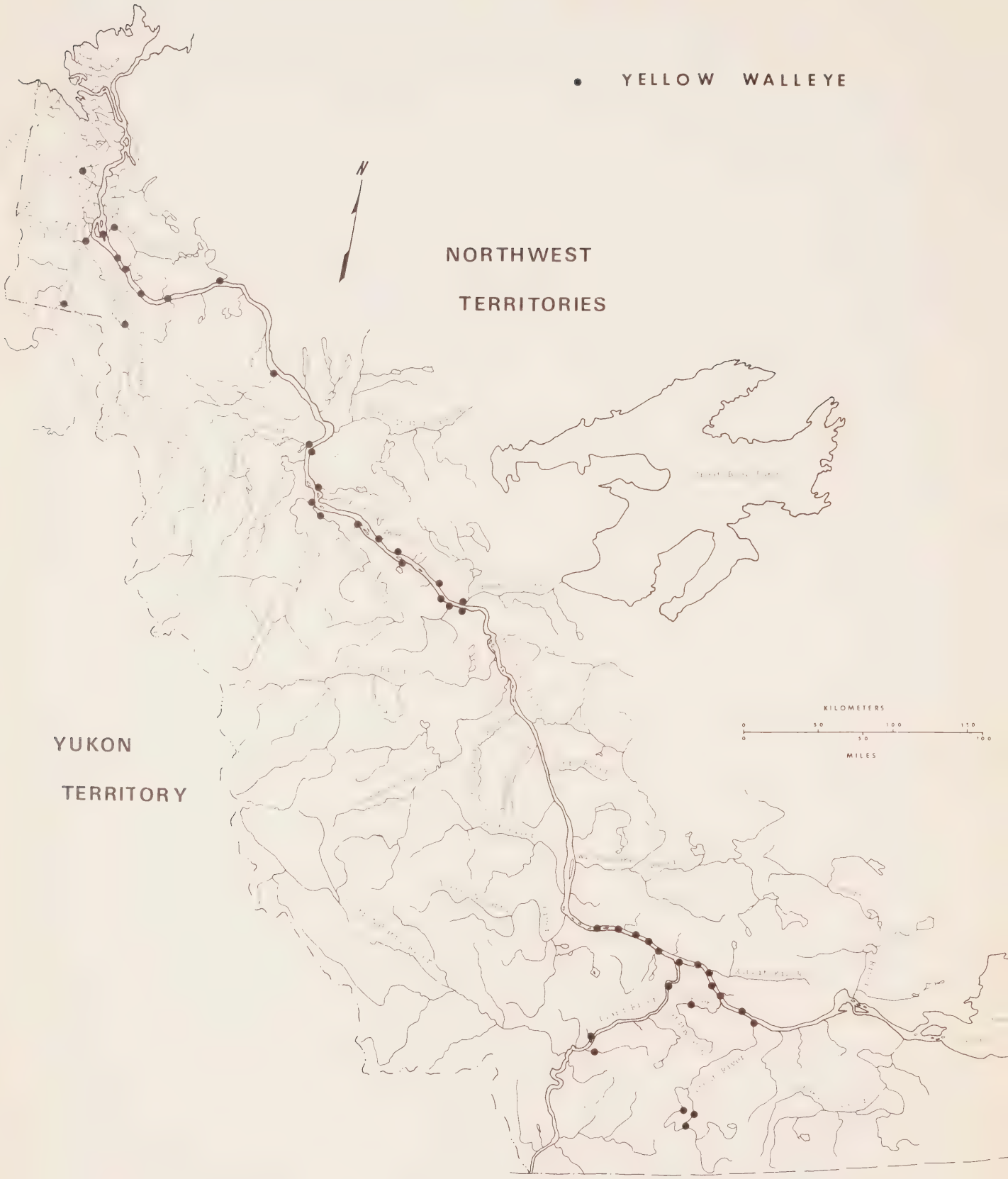

Fig. 20. Distribution of yellow walleye, Stizostedion vitreum vitreum (Mitchill), in the Mackenzie River study, 1971 and 1972.

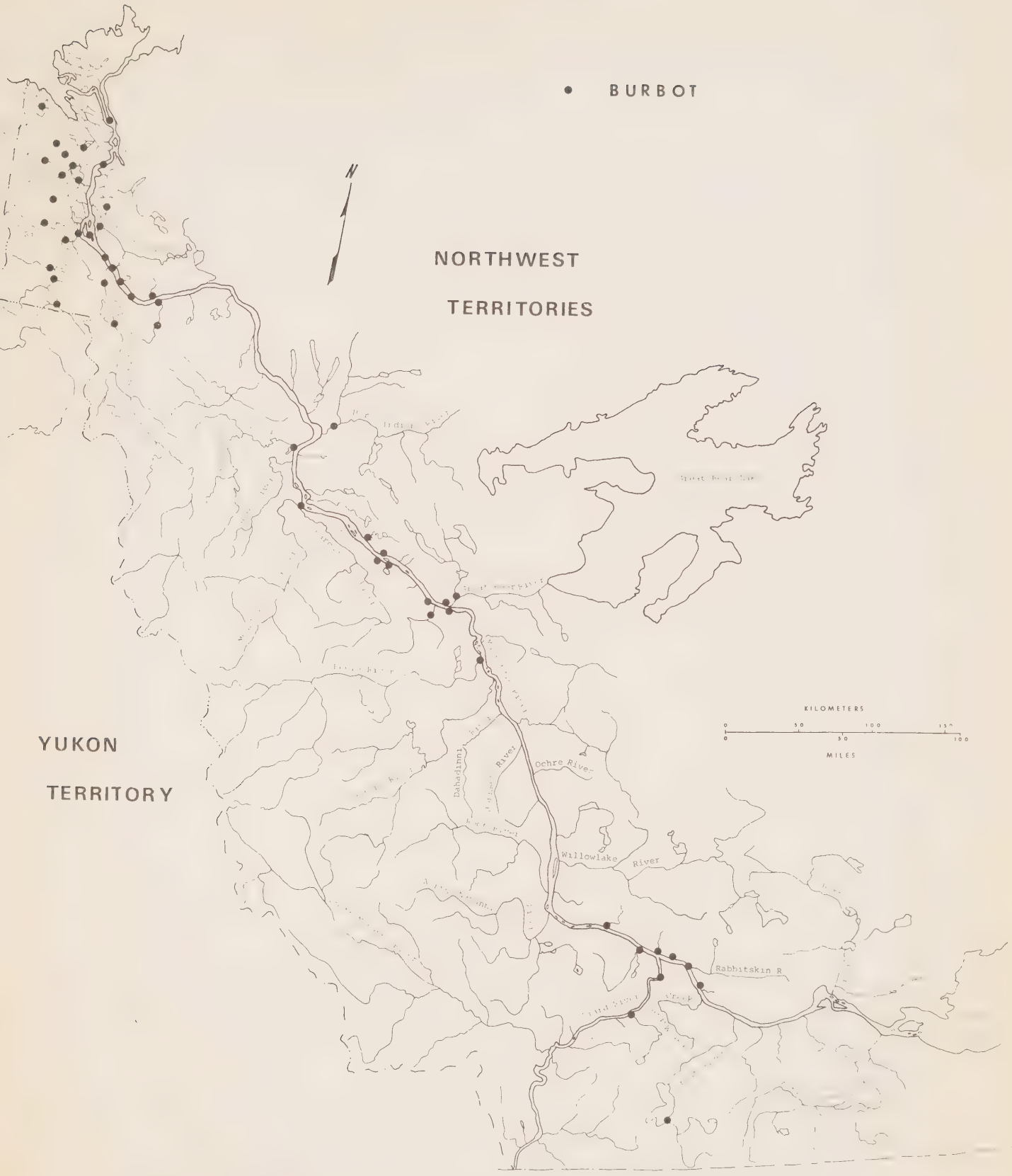

Fig. 21. Distribution of burbot, Lota lota (Linnaeus), in the Mackenzie River study, 1971 and 1972.

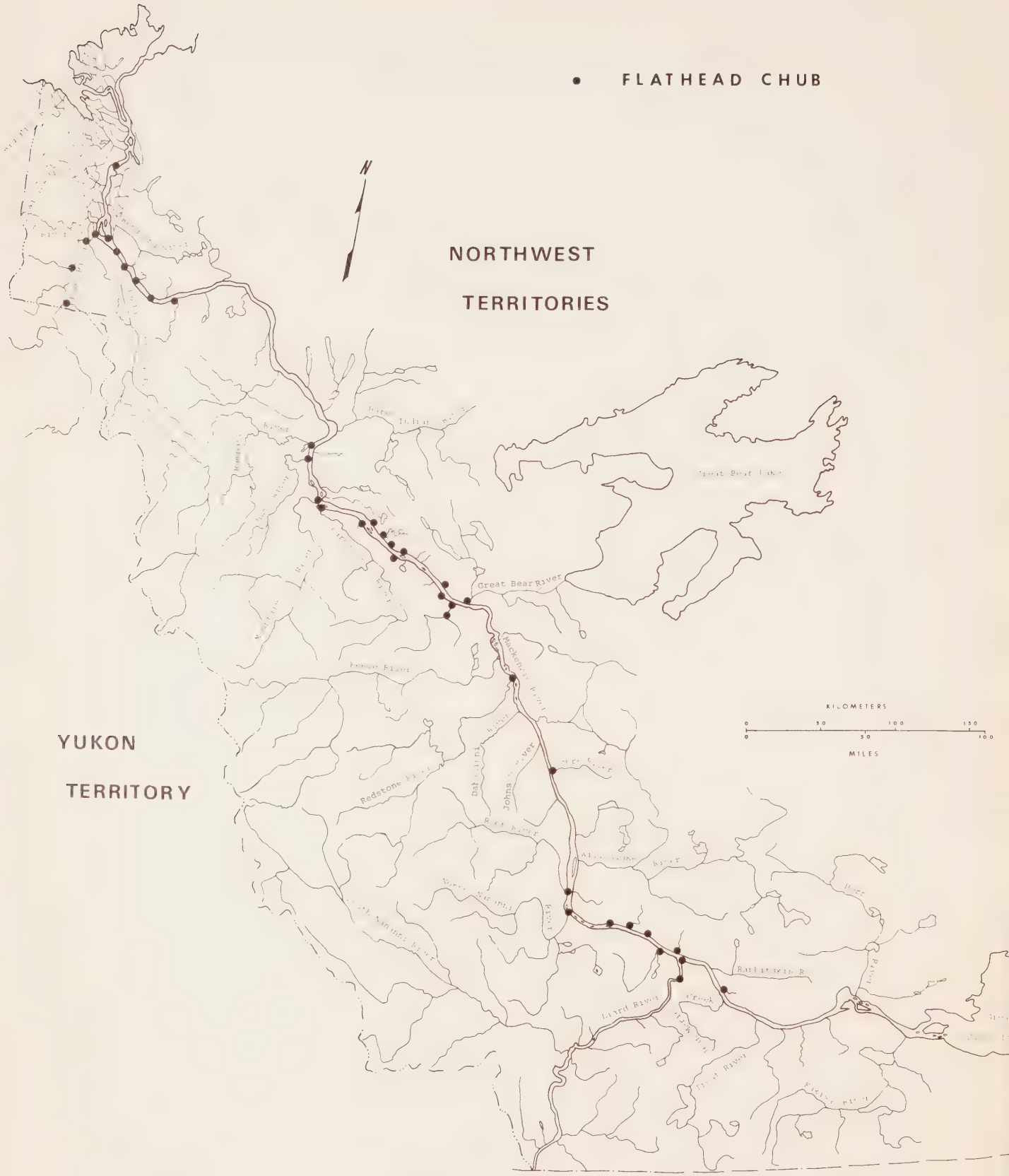

Fig. 22. Distribution of flathead chub, Platygobio gracilis (Richardson), in the Mackenzie River study, 1971 and 1972.

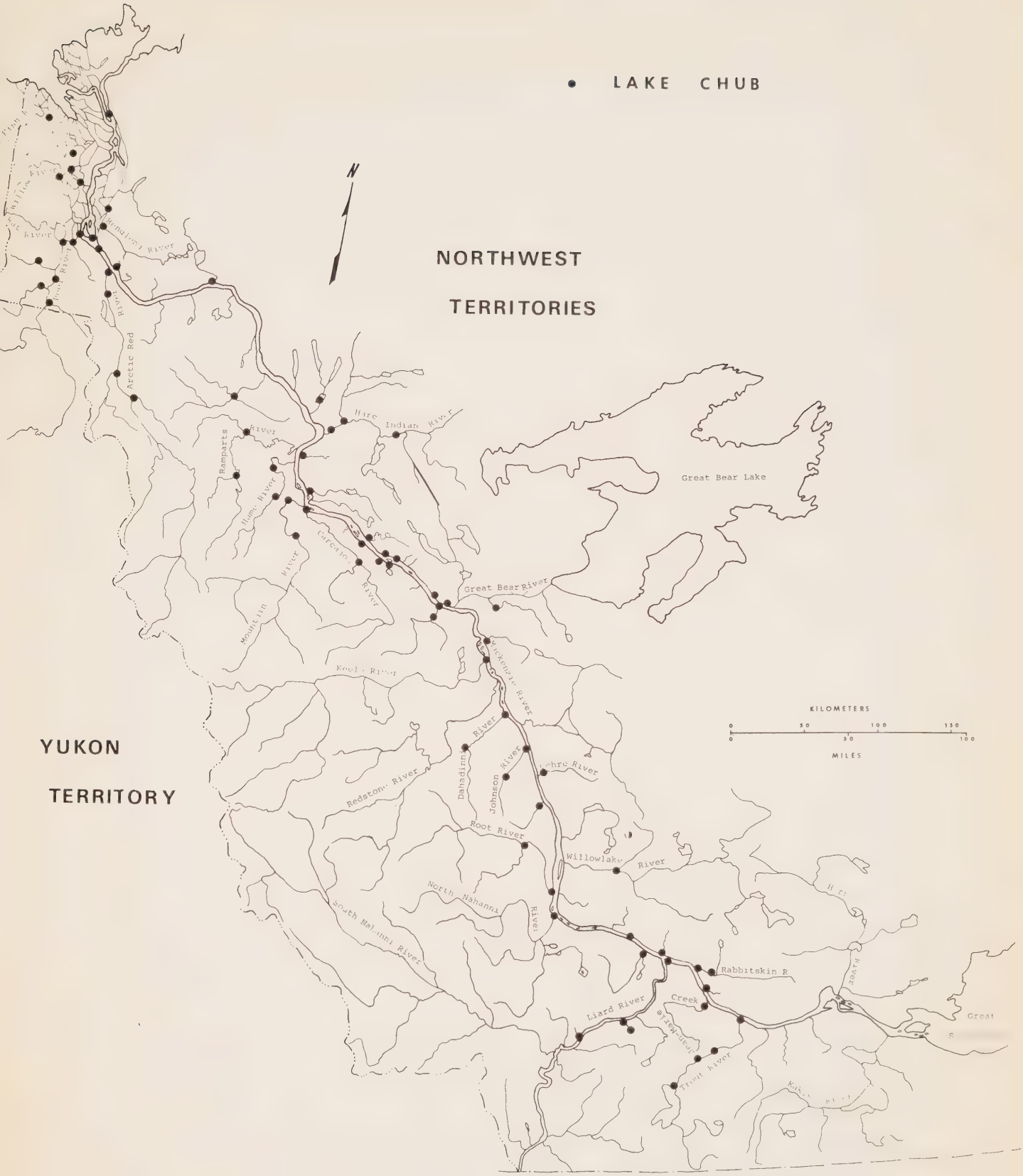

Fig. 23. Distribution of lake chub, Couesius plumbeus (Agassiz), in the Mackenzie River study, 1971 and 1972.

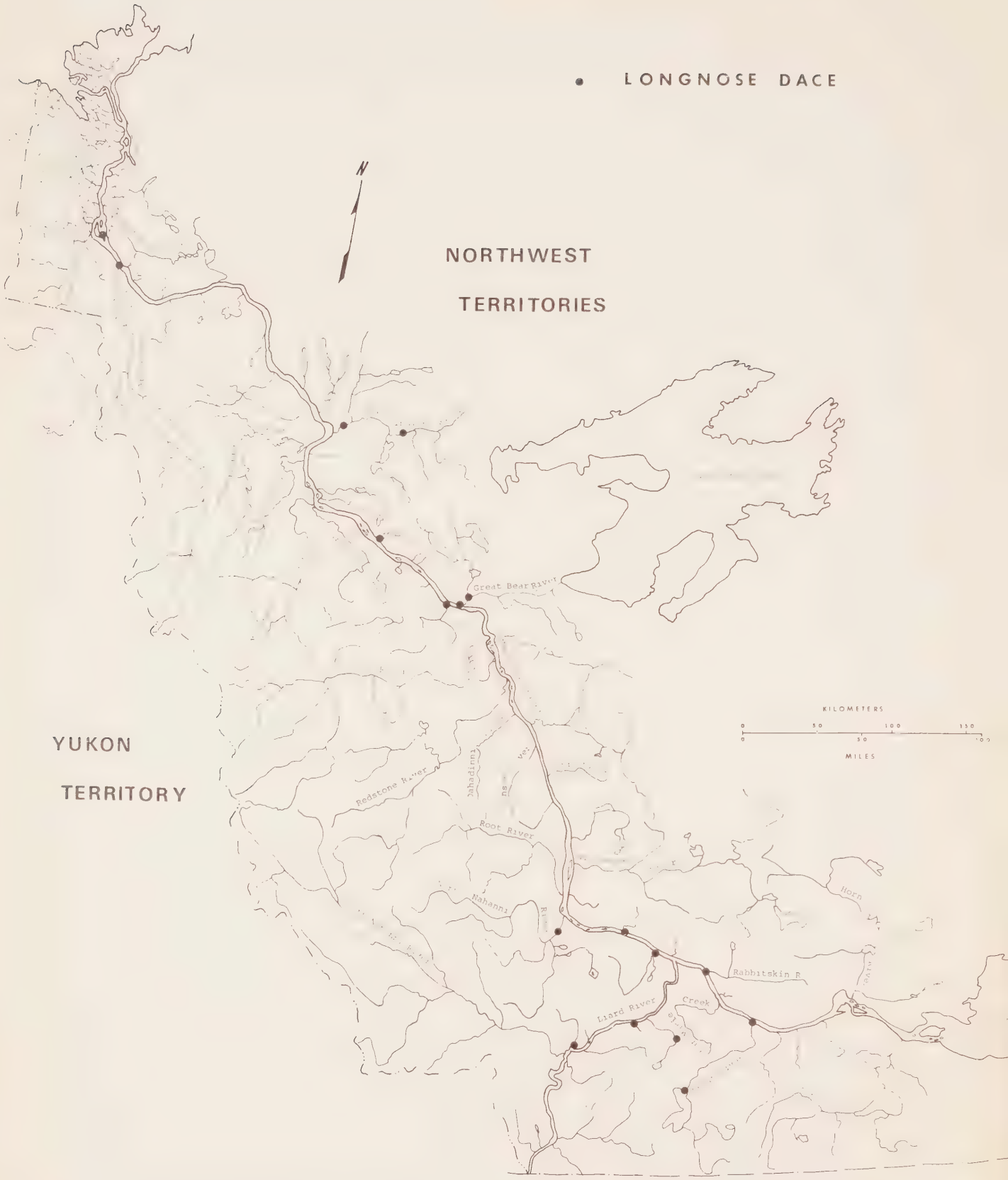

Fig. 24. Distribution of longnose dace, Rhinichthys cataractae (Valenciennes), in the Mackenzie River study, 1971 and 1972.

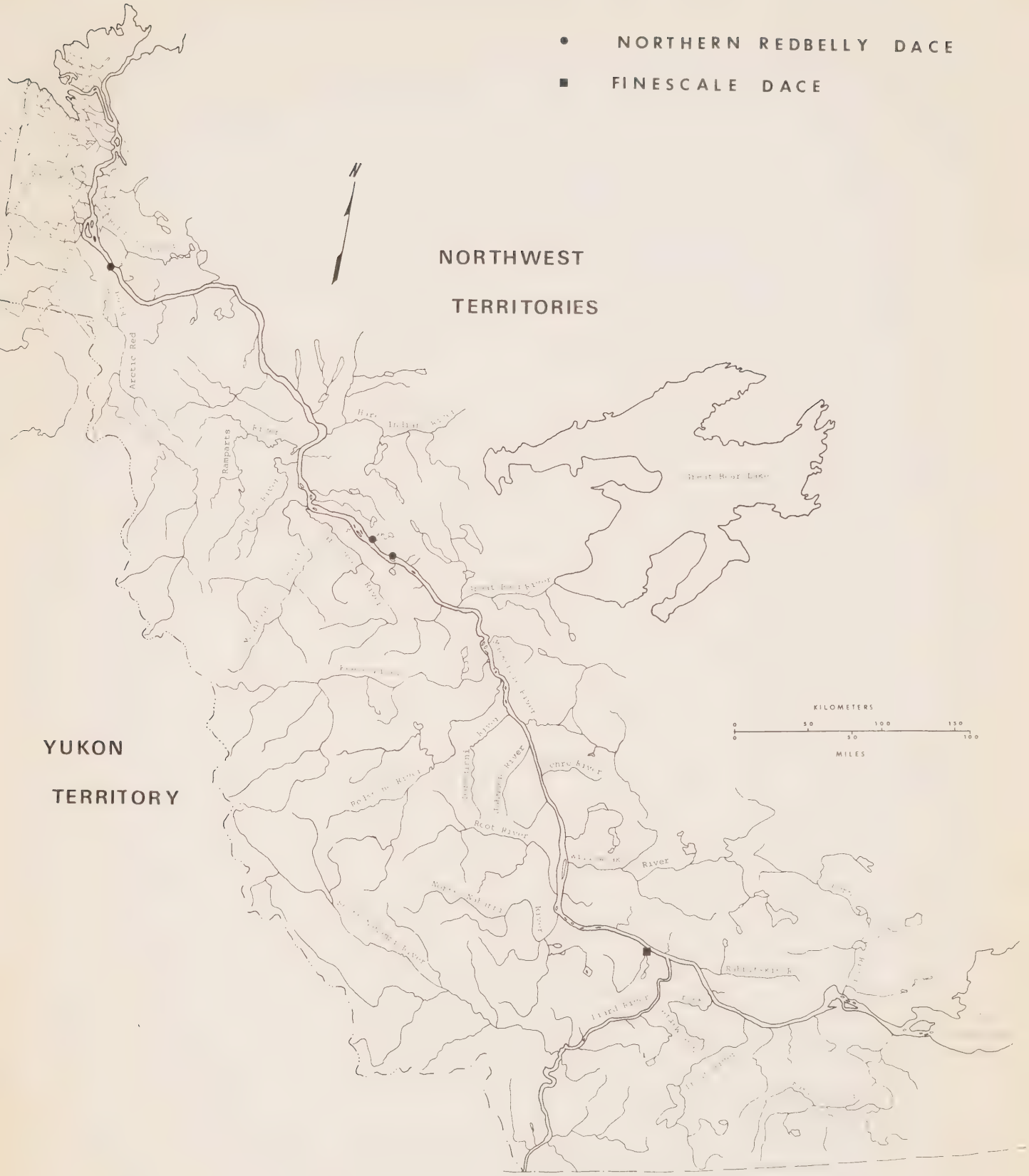

Fig. 25. Distribution of northern redbelly dace, Chrosomus eos (Cope) and finescale dace, Pfrille neogaea (Cope), in the Mackenzie River study, 1971 and 1972.

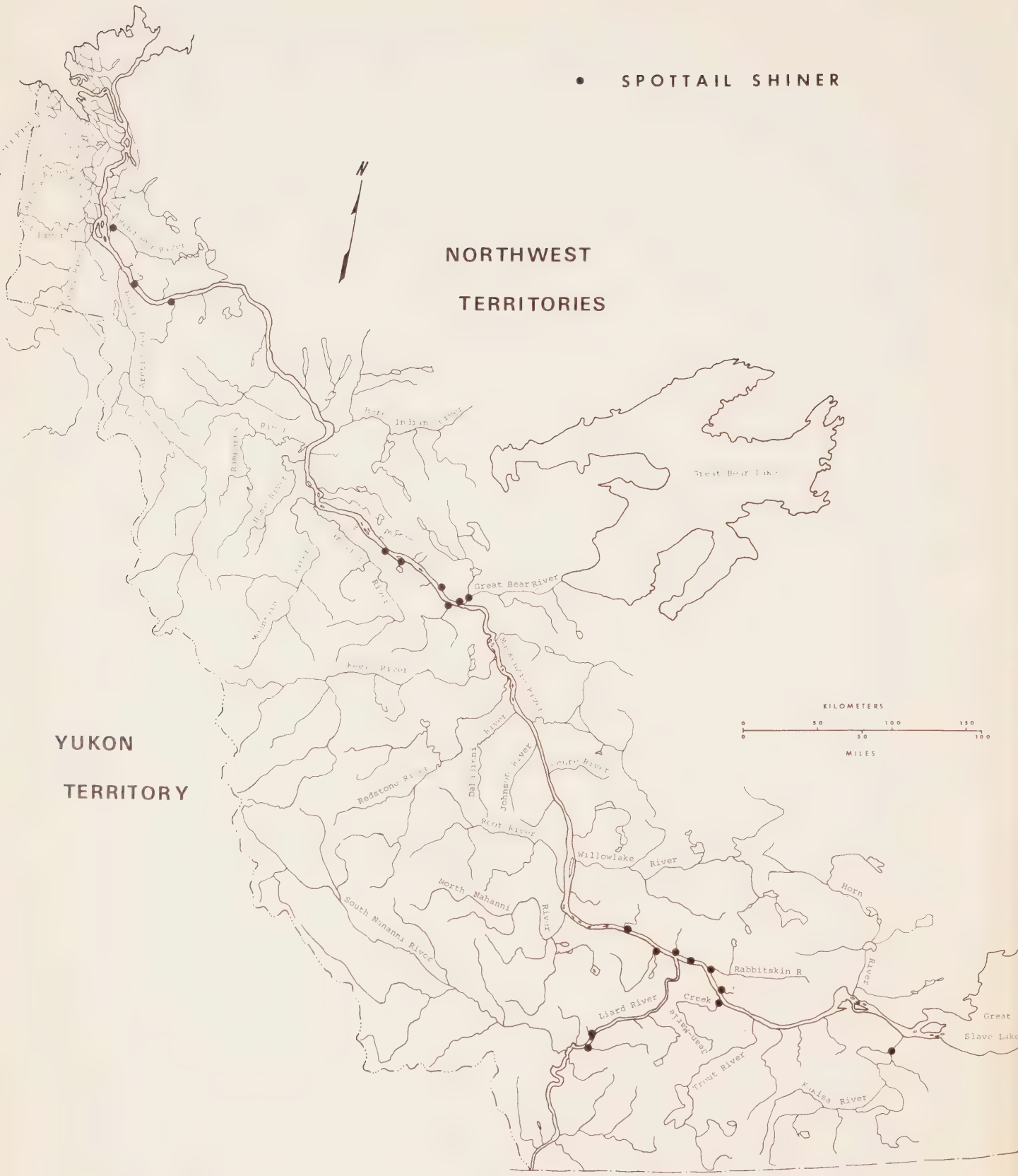

Fig. 26. Distribution of spottail shiner, Notropis hudsonius (Clinton), in the Mackenzie River study, 1971 and 1972.

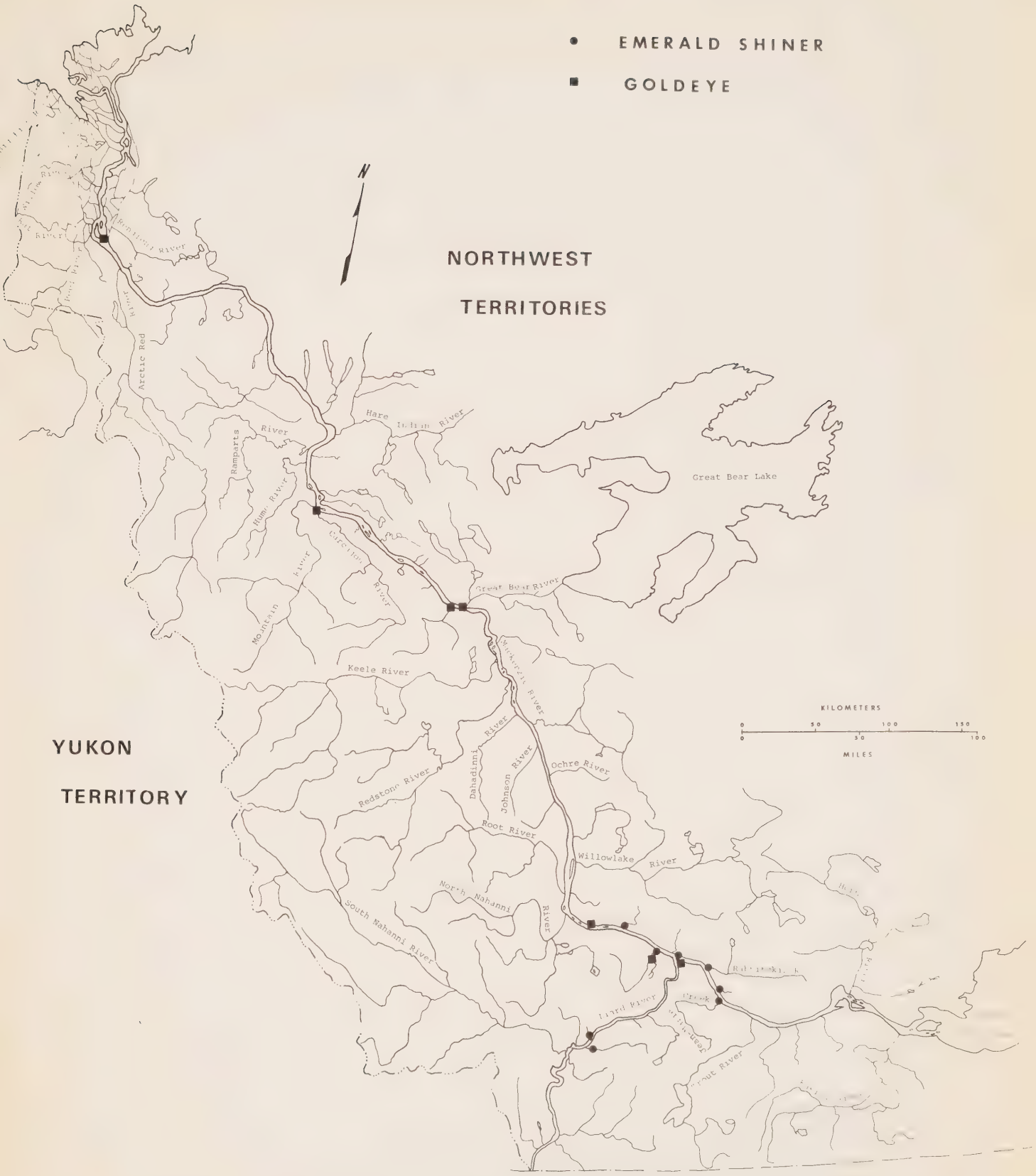

Fig. 27. Distribution of emerald shiner, N. atherinoides (Rafinesque) and goldeye, Hiodon alosoides (Rafinesque), in the Mackenzie River study, 1971 and 1972.

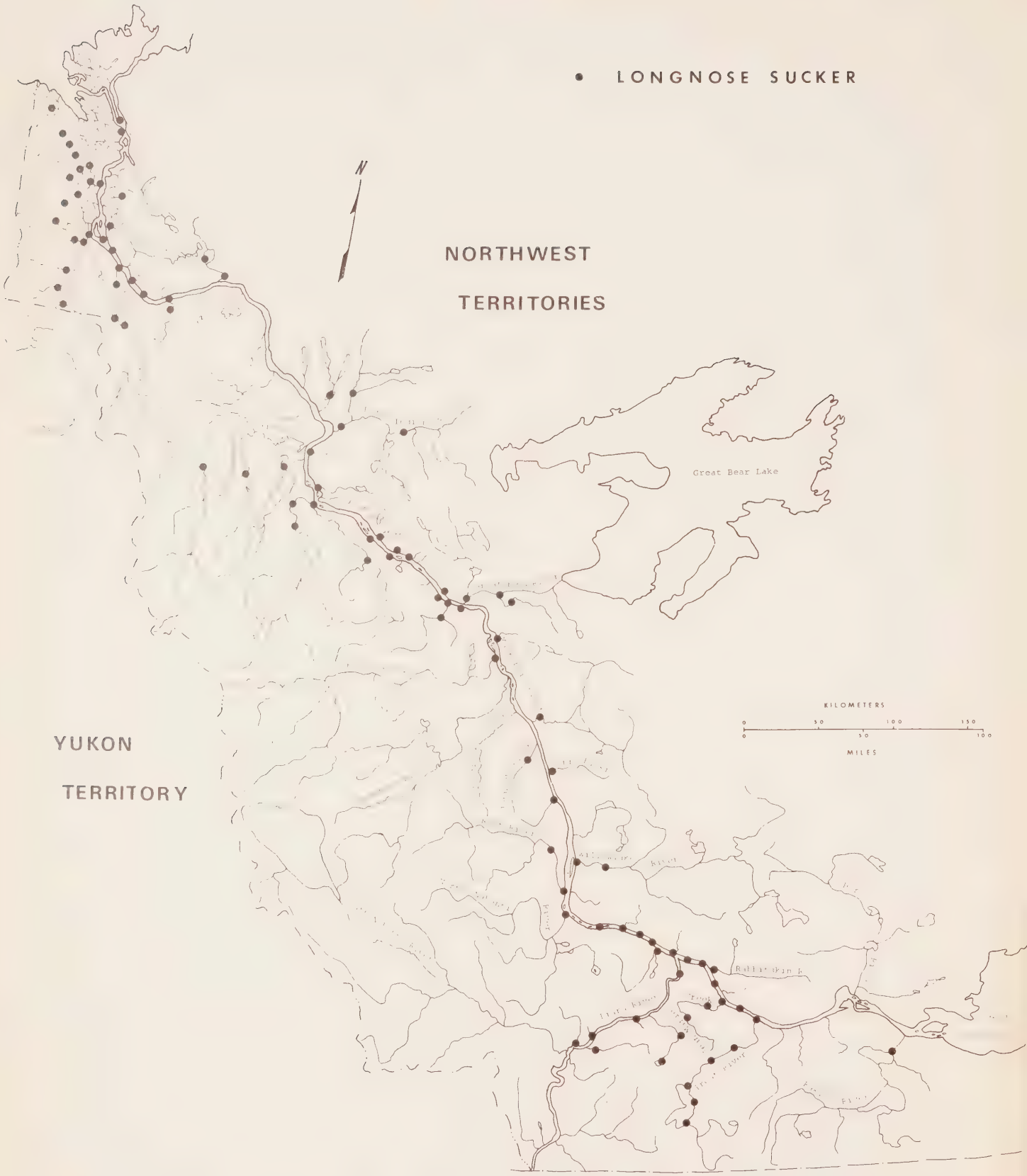

Fig. 28. Distribution of longnose sucker, Catostomus catostomus (Forster), in the Mackenzie River study, 1971 and 1972.

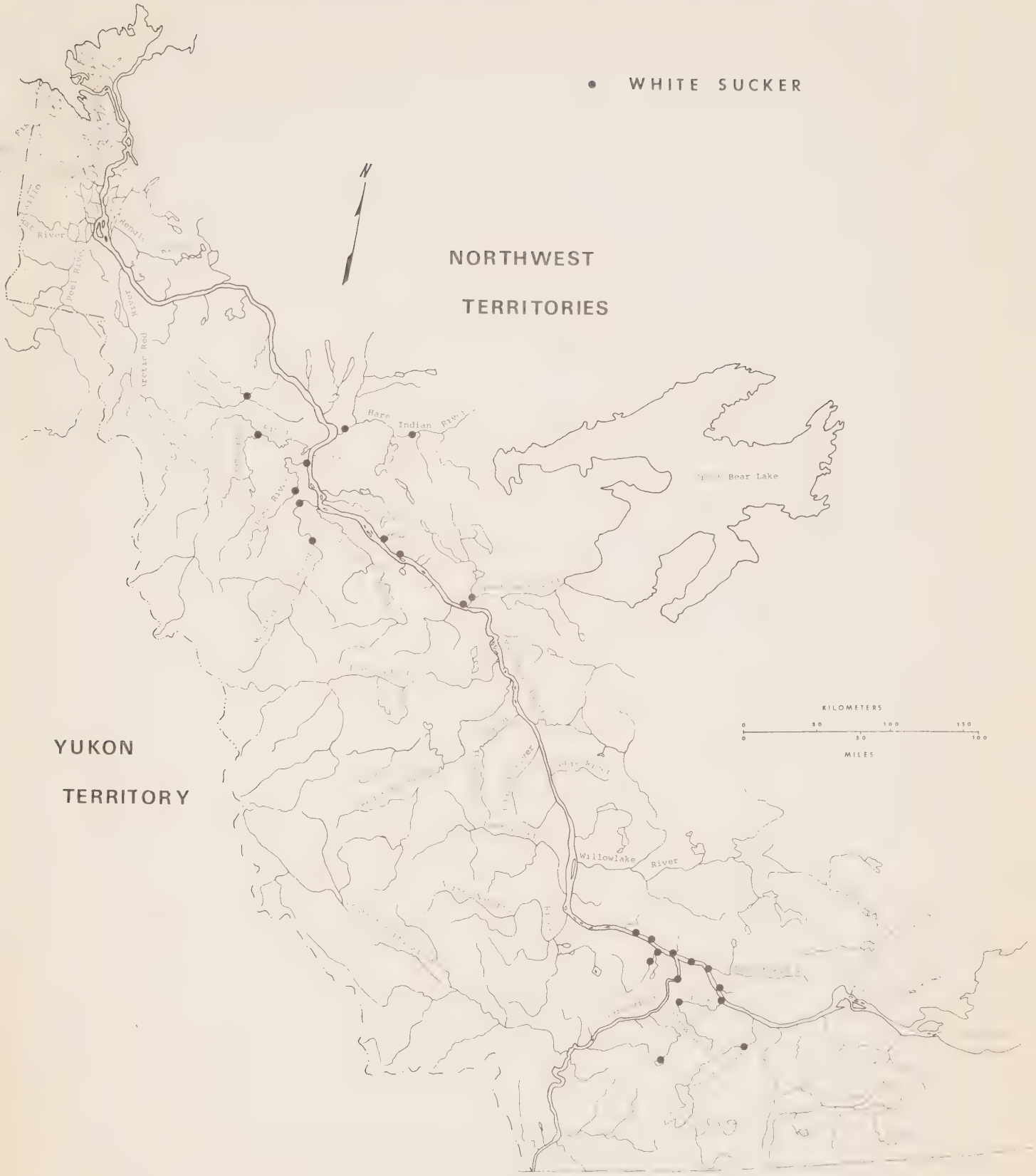

Fig. 29. Distribution of white sucker, C. commersoni (Lacepede), in the Mackenzie River study, 1971 and 1972.

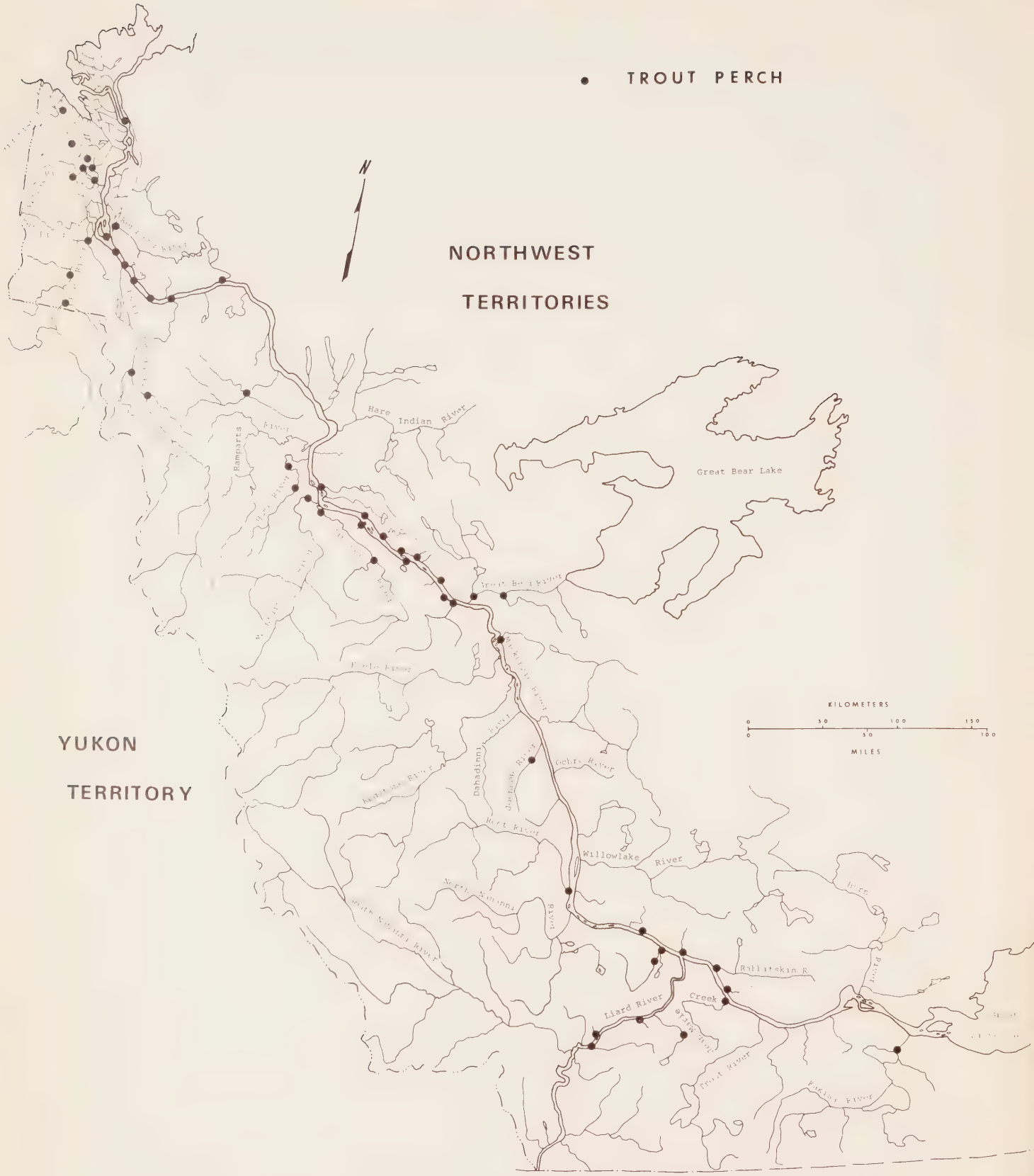

Fig. 30. Distribution of trout-perch, Percopsis omiscomaycus (Walbaum), in the Mackenzie River study, 1971 and 1972.

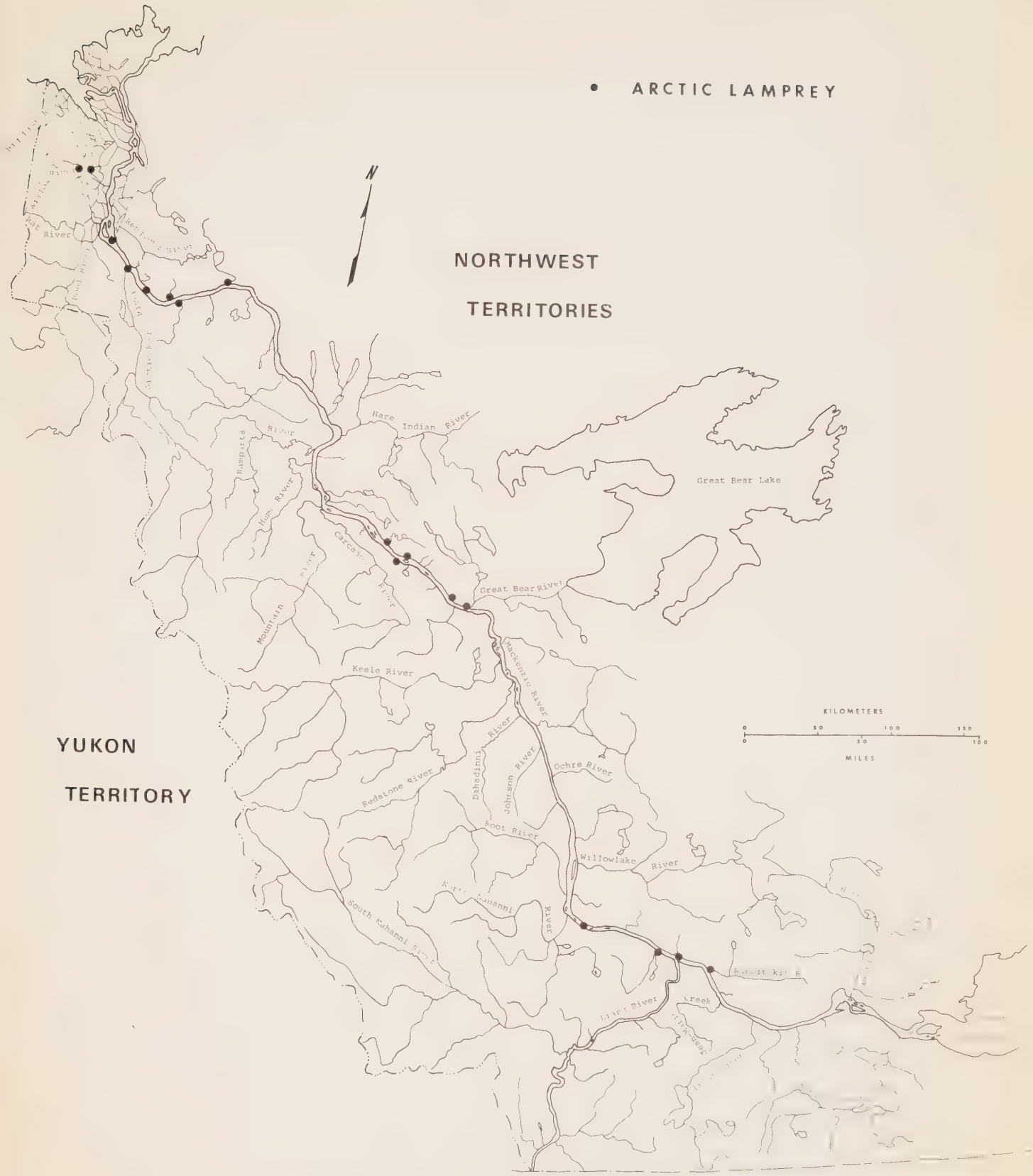

Fig. 31. Distribution of Arctic lamprey, Lampetra japonica (Martens), in the Mackenzie River study, 1971 and 1972.

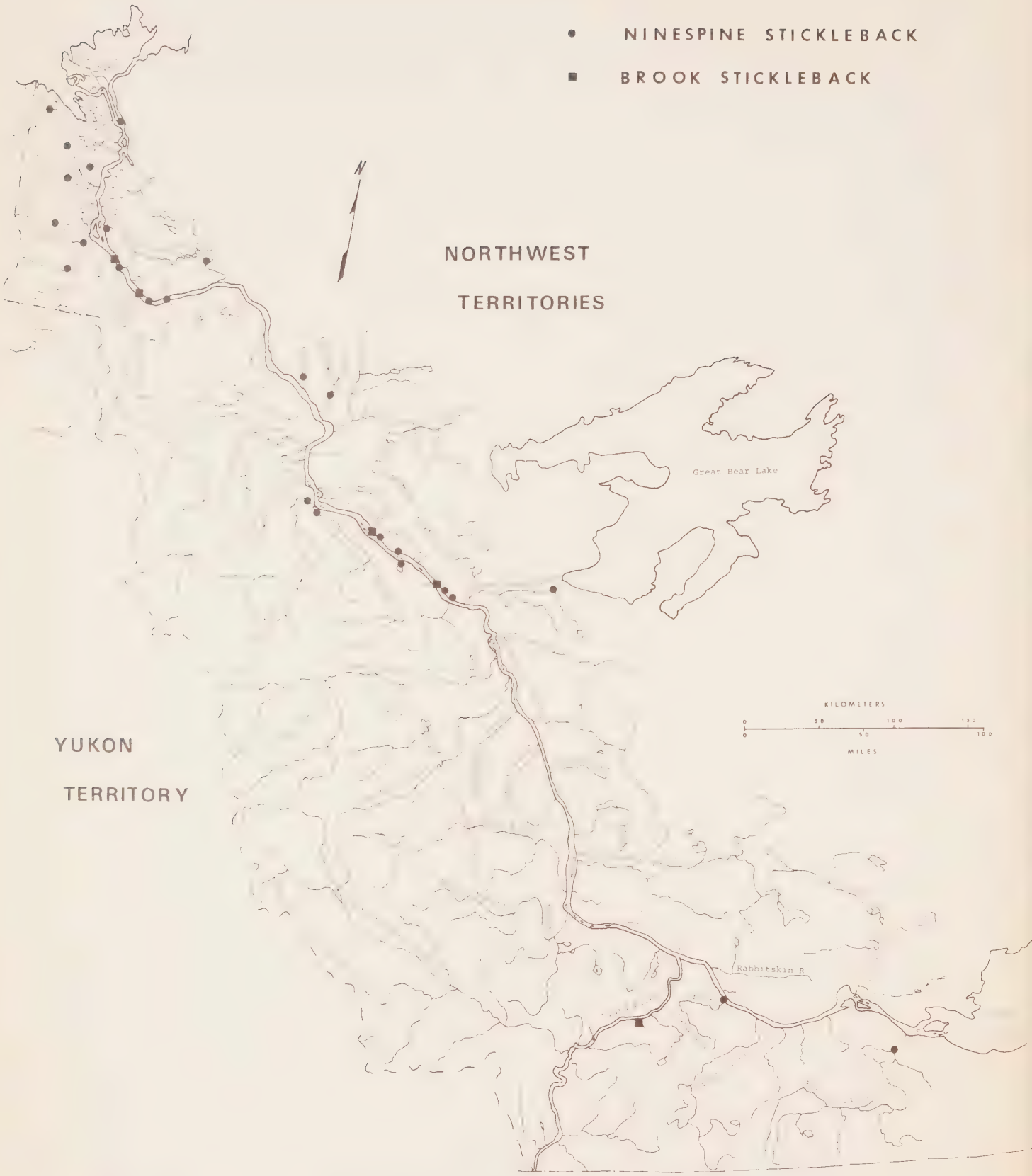

Fig. 32. Distribution of ninespine stickleback, Pungitius pungitius (Linnaeus), and brook stickleback, Culaea inconstans (Kirtland), in the Mackenzie River study, 1971 and 1972.

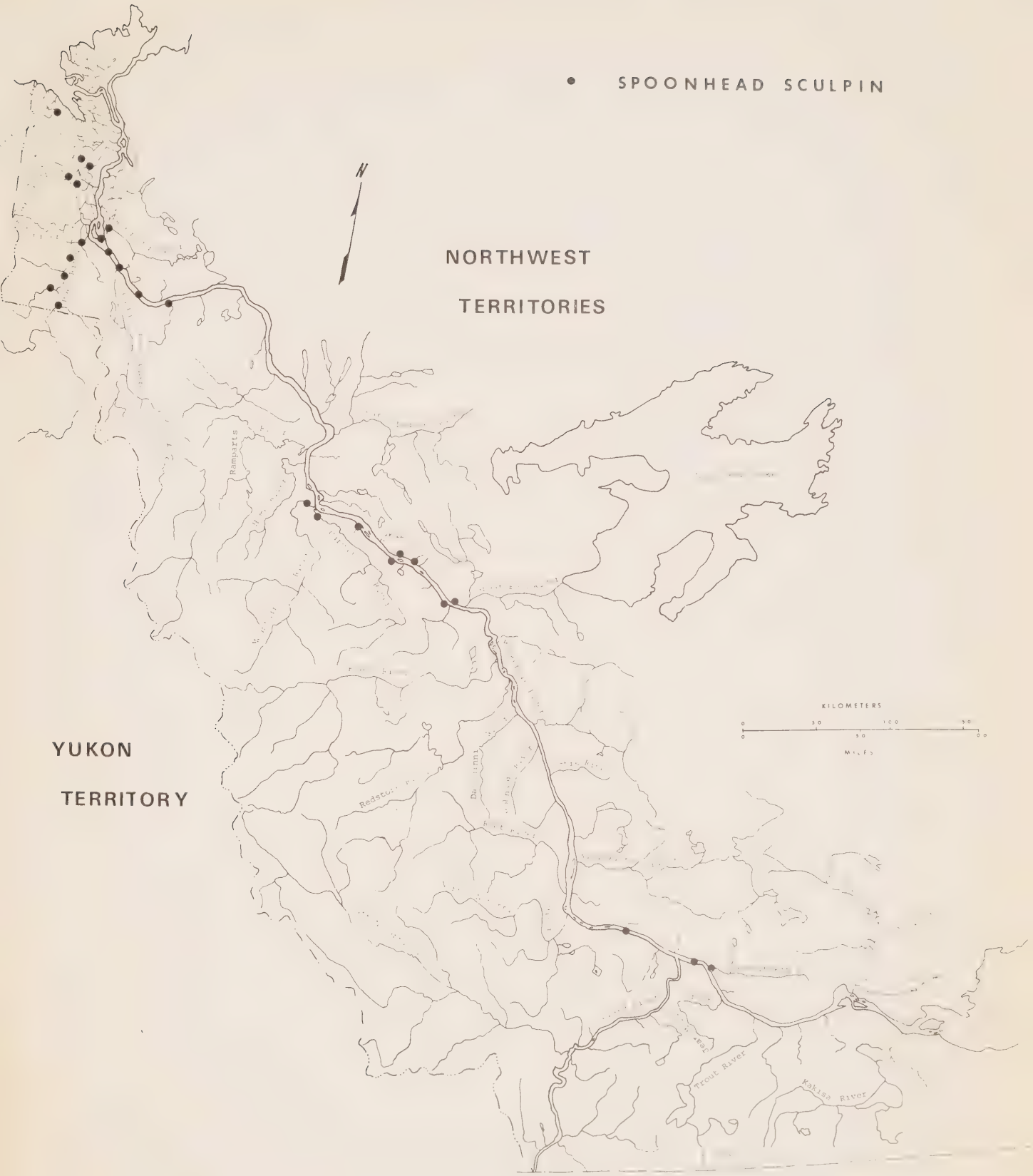

Fig. 33. Distribution of spoonhead sculpin, Cottus ricei (Nelson), in the Mackenzie River study, 1971 and 1972.

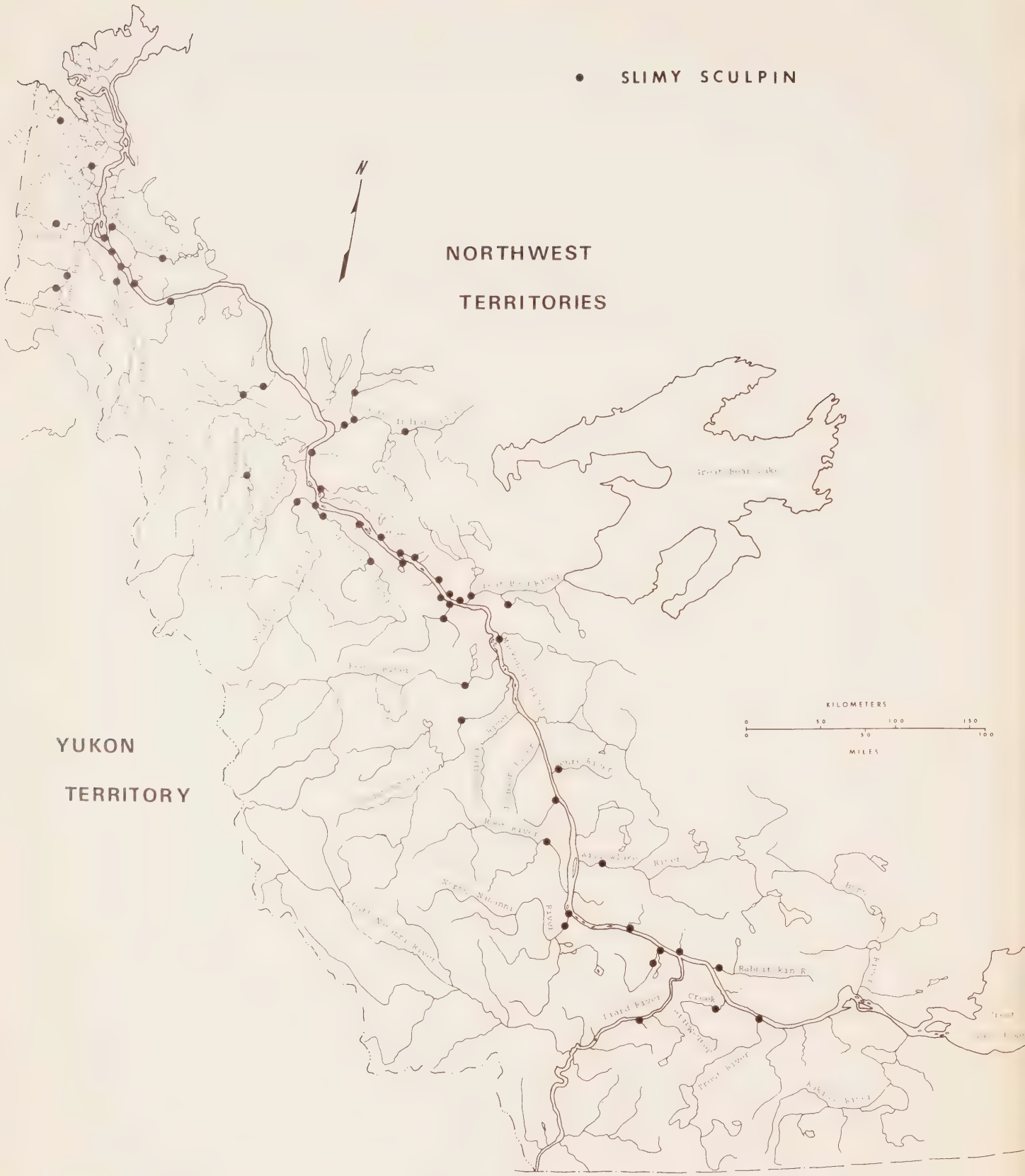

Fig. 34. Distribution of slimy sculpin, C. cognatus (Richardson), in the Mackenzie River study, 1971 and 1972.

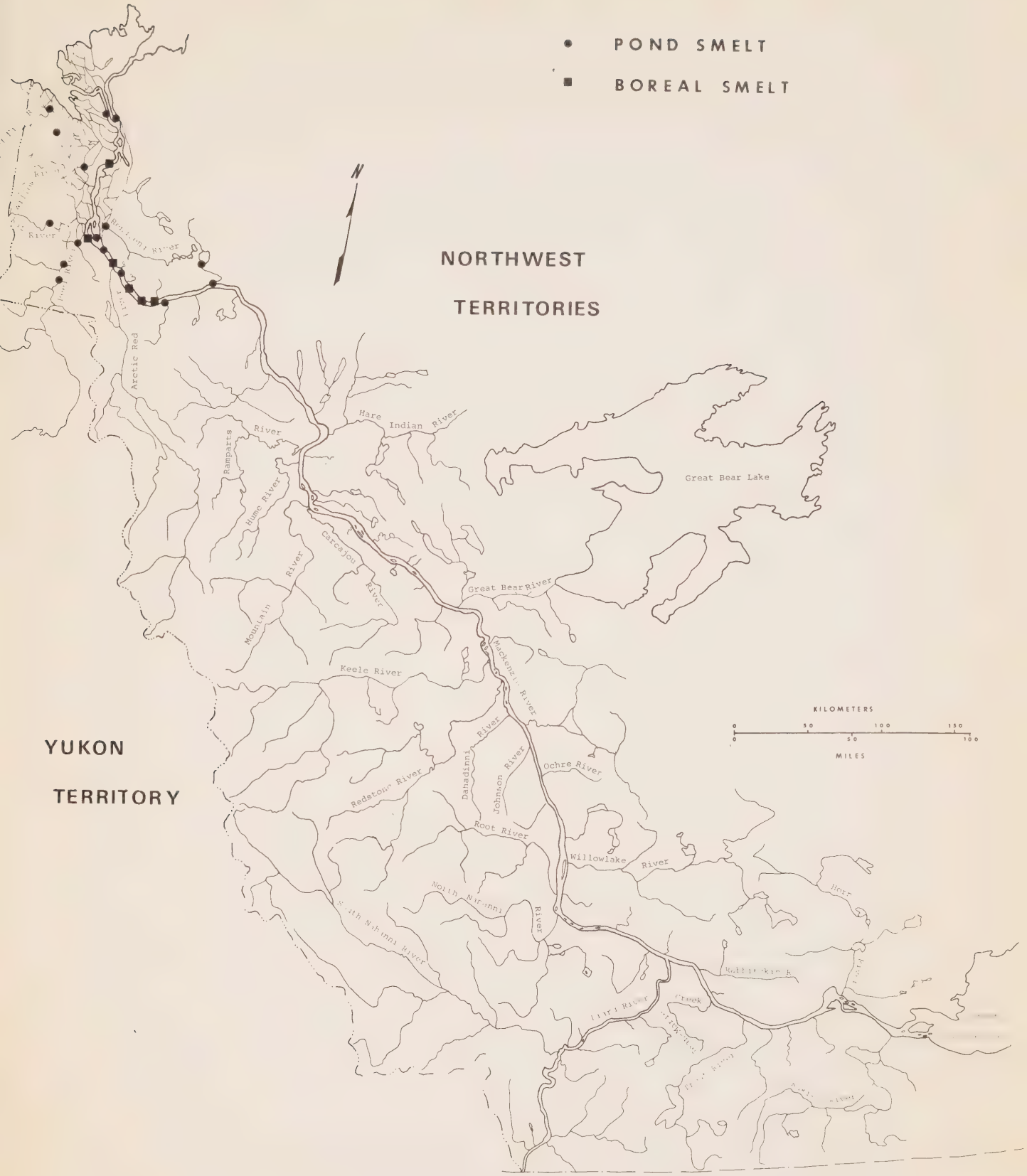

Fig. 35. Distribution of pond smelt, Hypomesus olidus (Pallas) and boreal smelt, Osmerus eperlanus (Linnaeus), in the Mackenzie River study, 1971 and 1972.

8.2 Numerical Abundance

At the Aklavik base, 79.18 per cent of the catch consisted of Arctic cisco, northern pike, humpback whitefish, broad whitefish and Arctic char (Table 2).

At the Arctic Red River base, 78.31 per cent of the catch consisted of humpback whitefish, broad whitefish, Arctic cisco, least cisco and northern pike (Table 2).

At the Fort McPherson base, 72.84 per cent of the catch consisted of Arctic cisco, broad whitefish, least cisco and longnose sucker (Table 2).

At the Norman Wells base, 72.73 per cent of the catch consisted of Arctic grayling, northern pike and longnose sucker (Table 2).

At the Fort Simpson base, 75.45 per cent of the catch consisted of northern pike, longnose sucker and humpback whitefish (Table 2).

Table 2. Numerical abundance and percent composition for fish species caught in gill nets and trap nets at each base during 1972 field season.

Species	Aklavik No. (%)	Arctic Red R. No. (%)	Ft. McPherson No. (%)	Norman Wells No. (%)	Ft. Simpson No. (%)	Total No. (%)
Arctic grayling	125 (1.39)	543 (8.13)	30 (3.91)	1862 (50.21)	299 (6.81)	2859 (11.65)
Lake trout	0	8 (0.12)	0	0	0	8 (0.03)
Arctic char	826 (9.16)	0	1 (0.13)	0	0	827 (3.37)
Chum salmon	0	10 (0.15)	1 (0.13)	1 (0.03)	0	12 (0.05)
Inconnu	502 (5.57)	465 (6.96)	38 (4.95)	267 (7.20)	154 (3.51)	1426 (5.81)
Humpback whitefish	1266 (14.04)	1391 (20.82)	33 (4.30)	64 (1.73)	637 (14.51)	3391 (13.81)
Broad whitefish	1090 (12.09)	1307 (19.57)	107 (13.95)	42 (1.13)	0	2546 (10.37)
Least cisco	533 (5.91)	755 (11.30)	101 (13.91)	13 (0.35)	22 (0.50)	1424 (5.80)
Arctic cisco	2599 (28.83)	1086 (16.26)	275 (35.85)	202 (5.45)	0	4162 (16.96)
Lake cisco	0	0	0	10 (0.27)	19 (0.39)	27 (0.11)
Round whitefish	23 (0.26)	0	17 (2.22)	23 (0.62)	7 (0.16)	70 (0.28)

Table 2. Continued

Species	Aklavik No. (%)	Arctic Red R. No. (%)	Ft. McPherson No. (%)	Norman Wells No. (%)	Ft. Simpson No. (%)	Total No. (%)
Mountain whitefish	0	0	0	0	75 (1.71)	75 (0.31)
Northern pike	1358 (15.06)	692 (10.36)	54 (7.04)	445 (12.00)	1988 (45.29)	4537 (18.48)
Yellow walleye	1 (0.01)	29 (0.44)	2 (0.26)	121 (3.26)	109 (2.48)	262 (1.07)
Burbot	622 (6.90)	75 (1.12)	18 (2.35)	58 (1.56)	34 (0.78)	807 (3.29)
Flathead chub	1 (0.01)	71 (1.06)	6 (0.78)	179 (4.83)	240 (5.45)	497 (2.03)
Longnose sucker	64 (0.71)	210 (3.14)	70 (9.13)	390 (10.52)	687 (15.65)	1421 (5.79)
White sucker	0	0	0	3 (0.08)	67 (1.53)	70 (0.28)
Boreal smelt	1 (0.01)	37 (0.55)	0	0	0	38 (0.16)
Goldeye	0	0	0	1 (0.03)	44 (1.00)	45 (0.18)
Other	5 (0.05)	1 (0.02)	0	27 (0.73)	8 (0.18)	41 (0.17)
Total	9016 (100.00)	6680 (100.00)	753 (100.00)	3708 (100.00)	4390 (100.00)	24547 (100.00)

8.3 Results of Tagging Operations

8.3.1 Tag Releases and Recaptures by Species and Base

Tables 3, 4, 5, 6 and 7 summarize the tag releases and recaptures by species for the Aklavik, Arctic Red River, Fort McPherson, Norman Wells and Fort Simpson respectively. Recaptures include domestic and sport fishery returns as well as those from gill netting and tagging operations of Fisheries crews.

Table 3. Summary of all tag releases and recaptures by species for the Aklavik base in 1972.

Species	Number Tagged	Per Cent of Total Number Tagged	Number Recaptured	Per Cent Recaptured
Arctic char	578	11.6	256	44.3
Arctic cisco	1664	33.3	74	4.4
Arctic grayling	43	0.9	23	53.5
Broad whitefish	470	9.4	74	15.7
Burbot	568	11.4	36	6.3
Humpback whitefish	616	12.3	63	10.2
Inconnu	233	4.7	14	6.0
Least cisco	81	1.6	8	9.9
Longnose sucker	25	0.5	0	0
Northern pike	714	14.3	44	6.2
Round whitefish	10	0.2	3	30.0
Yellow walleye	1	0.02	0	0
Total	5003	100.0	595	11.9

Table 4. Summary of all tag releases and recaptures by species for the Arctic Red River base in 1972.

Species	Number Tagged	Per cent of Total Number Tagged	Number Recaptured	Per cent Recaptured
Arctic cisco	501	15.2	8	1.6
Arctic grayling	394	11.9	15	3.8
Broad whitefish	807	24.4	219	27.1
Burbot	23	0.7	0	0.0
Humpback whitefish	823	24.9	63	7.7
Inconnu	127	3.8	26	20.5
Least cisco	336	10.2	1	0.3
Longnose sucker	40	1.2	2	5.0
Northern pike	251	7.6	14	5.6
Yellow walleye	5	0.2	1	20.0
Total	3307	100	349	10.6

Table 5. Summary of all tag releases and recaptures by species for the Fort McPherson base in 1972.

Species	Number Tagged	Per cent of Total Number Tagged	Number Recaptured	Per cent Recaptured
Arctic cisco	56	56.6	4	7.1
Burbot	9	9.1	0	0
Inconnu	2	2.0	1	50.0
Least cisco	18	18.2	2	11.1
Longnose sucker	9	9.1	0	0
Northern pike	2	2.0	0	0
Round whitefish	1	1.0	0	0
Flathead chub	2	2.0	0	0
Total	99	100.0	7	7.1

Table 6. Summary of all tag releases and recaptures by species for the Norman Wells base in 1972.

Species	Number Tagged	Per cent of Total Number Tagged	Number Recaptured	Per cent Recaptured
Arctic cisco	70	3.9	2	2.9
Arctic grayling	1130	64.1	23	2.0
Broad whitefish	1	0.1	1	100.0
Burbot	32	1.8	1	3.1
Humpback whitefish	35	1.9	1	2.9
Lake cisco	2	0.1	0	0
Least cisco	1	0.1	0	0
Inconnu	24	1.4	0	0
Longnose sucker	296	16.8	5	1.7
Northern pike	130	7.4	17	13.1
Round whitefish	6	0.3	0	0
White sucker	1	0.1	1	100.0
Yellow walleye	31	1.8	2	6.5
Whitefish	3	0.2	0	0
Total	1762	100.0	53	3.0

Table 7. Summary of all tag releases and recaptures by species for the Fort Simpson base in 1972.

Species	Number Tagged	Per cent of Total Number Tagged	Number Recaptured	Per cent Recaptured
Arctic grayling	101	6.6	2	2.0
Burbot	17	1.1	0	0
Goldeye	7	0.5	0	0
Humpback whitefish	97	6.3	6	6.2
Inconnu	15	0.9	0	0
Least cisco	1	0.1	0	0
Longnose sucker	448	29.1	12	2.7
Northern pike	712	46.2	140	19.7
Round whitefish	2	0.1	0	0
White sucker	46	2.9	0	0
Yellow walleye	46	2.9	1	2.2
Flathead chub	27	1.8	0	0
Lake chub	1	0.1	0	0
Mountain whitefish	17	1.1	1	5.9
Cisco	4	0.3	0	0
Total	1541	100	162	10.5

8.3.2 Population Estimates

Arctic Char - Big Fish River

Cache Creek, a tributary of the Big Fish River, near Aklavik, appears to be the major spawning area for Arctic char. Each year, domestic fishermen fish the area intensively with seine nets during October and November. Between 5,000 and 7,000 fish were taken this year by the domestic fishery. Estimates indicate that the population of catchable char in Cache Creek during October and November was between 12,000 and 17,000 fish.

Fig. 36. An Arctic char from the Big Fish River, 1972

Arctic Grayling - Swan Lake

It was estimated from tag recoveries that the population of catchable grayling in Swan Lake, Arctic Red River area, during 1972, was 5,000 to 7,000 fish.

Arctic Grayling - Three Day Lake-Stewart Creek

Seven hundred and fourteen grayling were tagged on the post-spawning run out of Three Day Lake, Norman Wells area. Conservative estimates of the number of catchable size grayling from the Three Day Lake drainrange from 13,000 to 17,000 fish.

Northern Pike - Fort Simpson

The population of catchable northern pike in the main stem of the Mackenzie River in the Fort Simpson study area ranged from 4,500 to 5,200 fish in 1972.

8.4 Migration Routes and Timing

8.4.1 Catch Analysis by Base

Catch summaries were calculated on a catch per unit of effort basis (number of fish/standard gang/hour) for index gill net catches by four-week intervals over the sampling period. Changes in numbers of fish caught over the season for major species are thus illustrated for Aklavik, Arctic Red River, Norman Wells and Fort Simpson (Fig. 37, 38, 39 and 40, respectively).

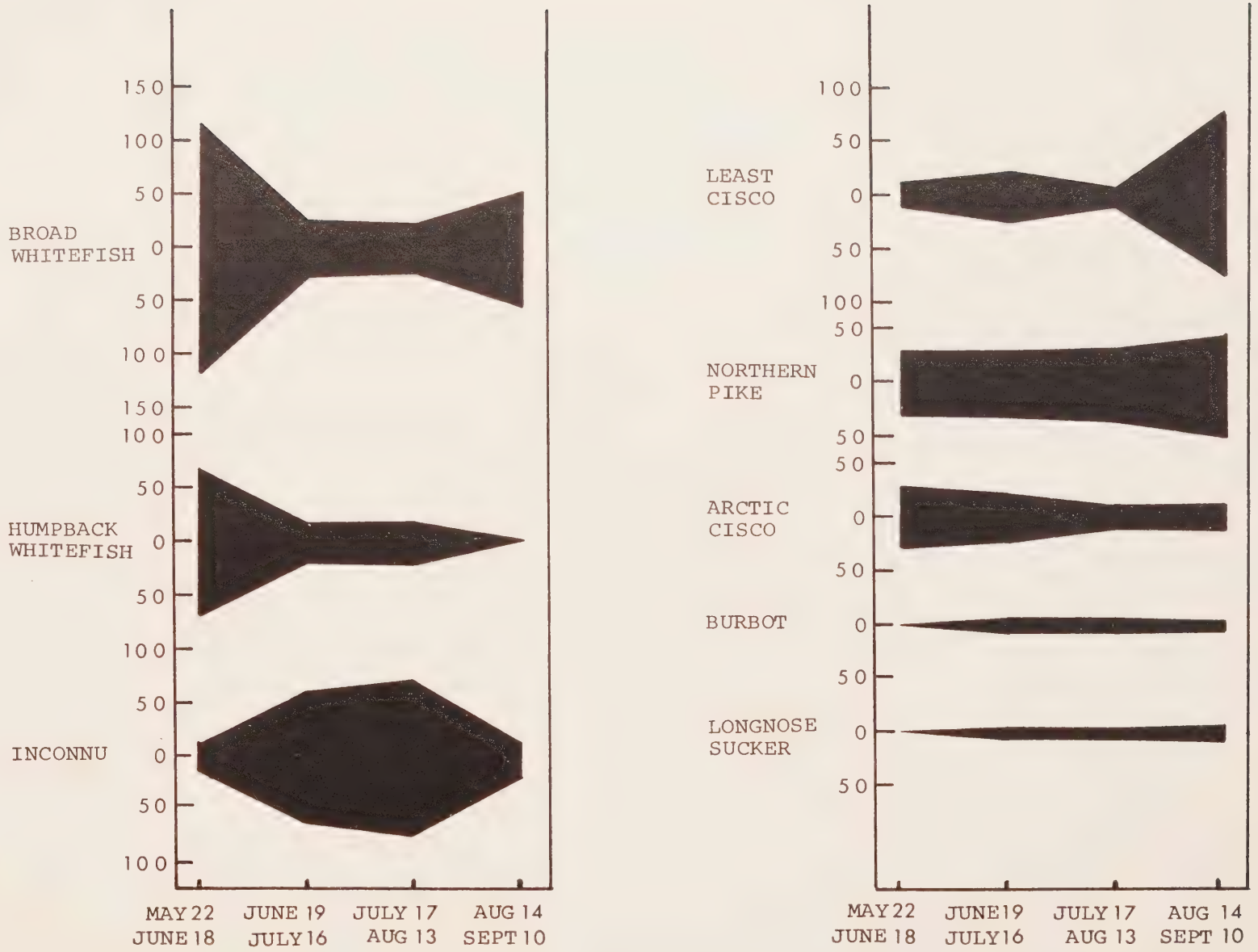

Fig. 37. Seasonal change of index gill net catches (catch per unit of effort x 1000) - Aklavik, 1972.

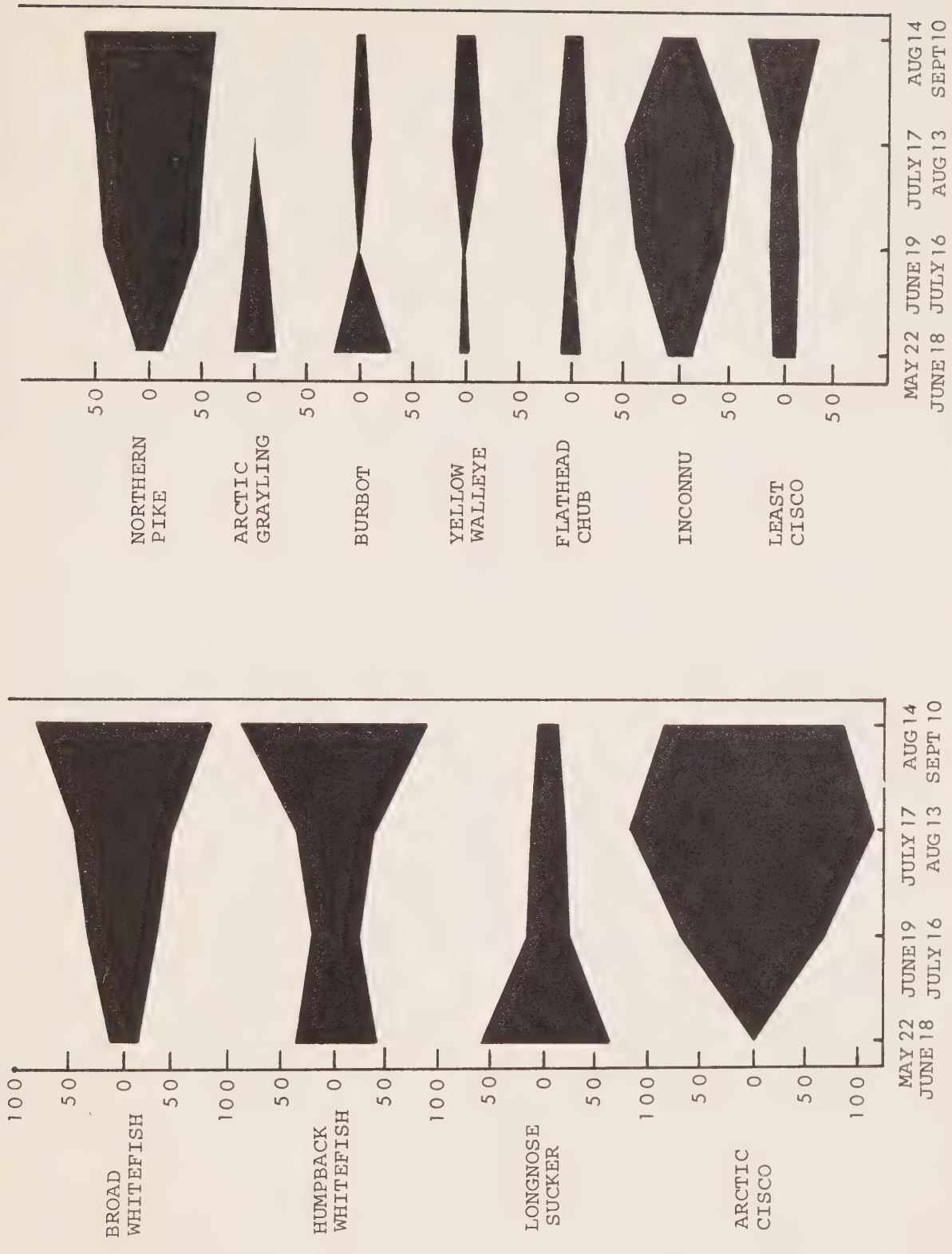

Fig. 38. Seasonal change of index gill net catches (catch per unit of effort x 1000) - Arctic Red River, 1972.

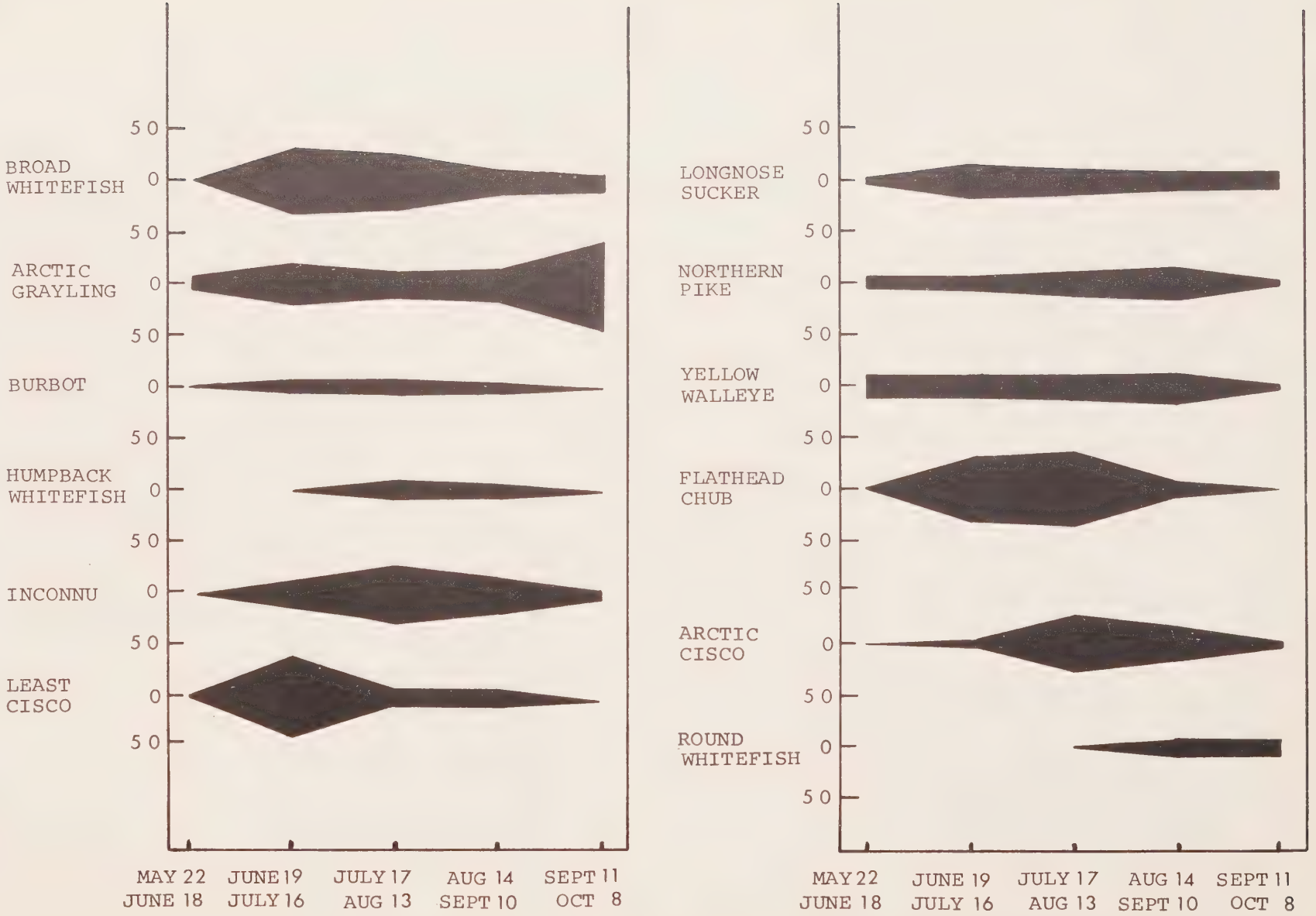

Fig. 39. Seasonal change of index gill net catches (catch per unit of effort x 1000) - Norman Wells, 1972.

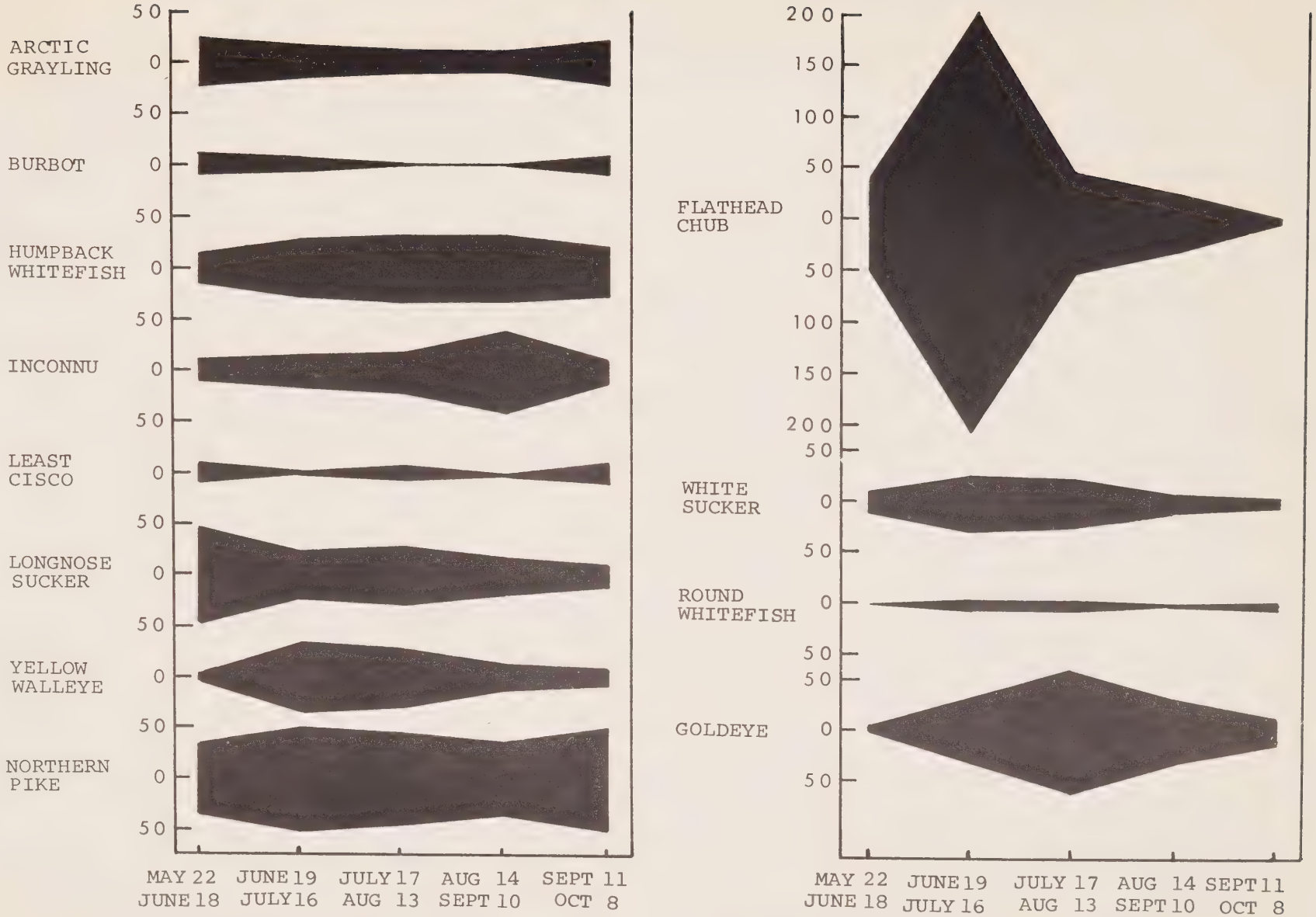

Fig. 40. Seasonal change of index gill net catches (catch per unit of effort x 1000) - Fort Simpson, 1972.

8.4.2 Domestic Catch Analysis

During the study period, an estimated 4,000 inconnu, 9,500 whitefish and 19,000 cisco were taken in the Peel River domestic fishery. These totals exclude fish consumed at camps by humans and dogs. Small numbers of round whitefish, yellow walleye, flathead chub, chum salmon and Arctic char were noted in a few catches. Northern pike, burbot and longnose suckers were taken at all camps throughout the study period, but since few of these were kept by the fisherman, accurate catch estimates cannot be made.

Reports from local residents indicated that an upstream run of inconnu had occurred just after breakup in June. Although inconnu catches generally decreased at the end of August, a definite downstream migration occurred at freeze-up on the Peel River.

Since catch monitoring ceased prior to major spawning runs, no significant seasonal change was noted in whitefish catches. Humpback whitefish were most abundant at the mouth of the Peel River and on the Husky Channel, comprising approximately 30 per cent of the whitefish catch. Upstream, humpback whitefish were estimated at less than 10 per cent of the total whitefish catch.

Arctic cisco were numerous at all camp locations except those on the Husky Channel. Upstream movements continued until August 25 at the mouth of the Peel and to September 15 upstream. Local residents reported a significant downstream migration shortly after freeze-up of the Peel, in early October. Few least cisco were noted in domestic catches.

8.4.3 Movements of Tagged Fish

Ranges for distance travelled from release point and the elapsed time between release and recovery of tagged fish from each river base are shown in Tables 8, 9, 10, 11 and 12. Note that fish recaptured within a day, close to the site of release, were excluded.

In the following description of major fish movements, Norman Wells and Fort Simpson are presented separately; however, since major migrations occur between the delta and the Arctic Red River region, data from Aklavik, Arctic Red River and Fort McPherson are described jointly.

8.4.3.1 Aklavik, Arctic Red River, Fort McPherson

Arctic Grayling

Arctic grayling tag returns came from two areas only. Twenty-three came from a group tagged on September 18-19 in "Fish Hole" on Cache Creek, a tributary of the Big Fish River (Fig. 41; loc. 3). These fish, caught after 6 to 48 days, had not moved out of "Fish Hole".

Of 394 grayling tagged in the Arctic Red River area, 85 were tagged at the mouth of Swan Creek (loc. 23) on June 4. Five of those tagged at the mouth were recaptured 22.5 km (14 miles) upstream at Swan Lake (loc. 22) on July 4 and September 15.

Arctic Char

Two Arctic char runs were observed by the Fisheries Service during August and September, 1972. Of 273 fish tagged on the lower part of Big Fish River (Fig. 41; loc. 1) between August 10 and 16, 52 were recaptured within a week by local fishermen in the vicinity of release. Sixty-nine fish were recaptured at "Fish Hole" in Cache Creek 80.5 km (50 miles) upstream between September 19 and November 5. Forty-four per cent (117) of 265 char tagged in "Fish Hole" in September were recaptured in the same area.

Table 8. Range of distance travelled from point of release and elapsed time between release and recovery for fish tagged by the Aklavik crew.

Species	Distance							
	0-14 km (0-9 miles)		15-49 km (10-30 miles)		50-79 km (31-50 miles)		80 km (50 miles)	
	Number	Days	Number	Days	Number	Days	Number	Days
Arctic char	127	2-63	1	6	2	5-14	74	34-88
Arctic cisco	19	2-22						
Arctic grayling	23	5-47						
Broad whitefish	29	2-35	6	4-63	6	14-70	18	23-63
Burbot	28	4-62	6	5-54	1	56		
Humpback whitefish	40	2-32	2	4-73	2	53-62	3	9-41
Inconnu	7	3-17					1	78
Least cisco	4	3-7						
Northern pike	28	2-114	2	16-23	1	22	1	15
Round whitefish	1	2						

Table 9. Range of distance travelled from point of release and elapsed time between release and recovery for fish tagged by the Arctic Red River crew.

Species	Distance							
	0-14 km (0-9 miles)		15-49 km (10-30 miles)		50-79 km (31-50 miles)		80 km (50 miles)	
	Number	Days	Number	Days	Number	Days	Number	Days
Arctic cisco			1	4			3	22-99
Arctic grayling	2	73	5	29-102				
Broad whitefish	145	2-90	19	0-98	4	15-79	13	4-26
Humpback whitefish	34	2-73	3	14-43	2	34-83	11	4-95
Inconnu	6	6-51	3	5-61	5	9-94	12	8-45
Longnose sucker					1	13		
Northern pike	4	2-22			1	84	1	34
Yellow walleye					1	51		

Table 10. Range of distance travelled from point of release and elapsed time between release and recovery for fish tagged by the Fort McPherson crew.

Species	Distance							
	0-14 km (0-9 miles)		15-49 km (10-30 miles)		50-79 km (31-50 miles)		80 km (50 miles)	
	Number	Days	Number	Days	Number	Days	Number	Days
Arctic cisco							2	34-50
Inconnu	1	6						
Least cisco	1	6	1	1				

Table 11. Range of distance travelled from point of release and elapsed time between release and recovery for fish tagged by the Norman Wells crew.

Species	Distance							
	0-14 km (0-9 miles)		15-49 km (10-30 miles)		50-79 km (31-50 miles)		80 km (50 miles)	
	Number	Days	Number	Days	Number	Days	Number	Days
Arctic grayling	8	2-9			4	9-27	3	18-60
Arctic cisco							1	30
Burbot	1	19						
Humpback whitefish	1	7						
Longnose sucker	1	7						
Northern pike	7	1-68						
White sucker							1	67
Yellow walleye	2	3						

Table 12. Range of distance travelled from point of release and elapsed time between release and recovery for fish tagged by the Fort Simpson crew.

Species	Distance							
	0-14 km (0-9 miles)		15-49 km (10-30 miles)		50-79 km (31-50 miles)		80 km (50 miles)	
	Number	Days	Number	Days	Number	Days	Number	Days
Arctic grayling			1	6				
Humpback whitefish	2	1-52	2	37-49				
Longnose sucker	6	14-57	1	7	1	3		
Northern pike	86	1-89	22	2-106	5	28-136	1	7
Yellow walleye	1	21						
Mountain whitefish			1	22				

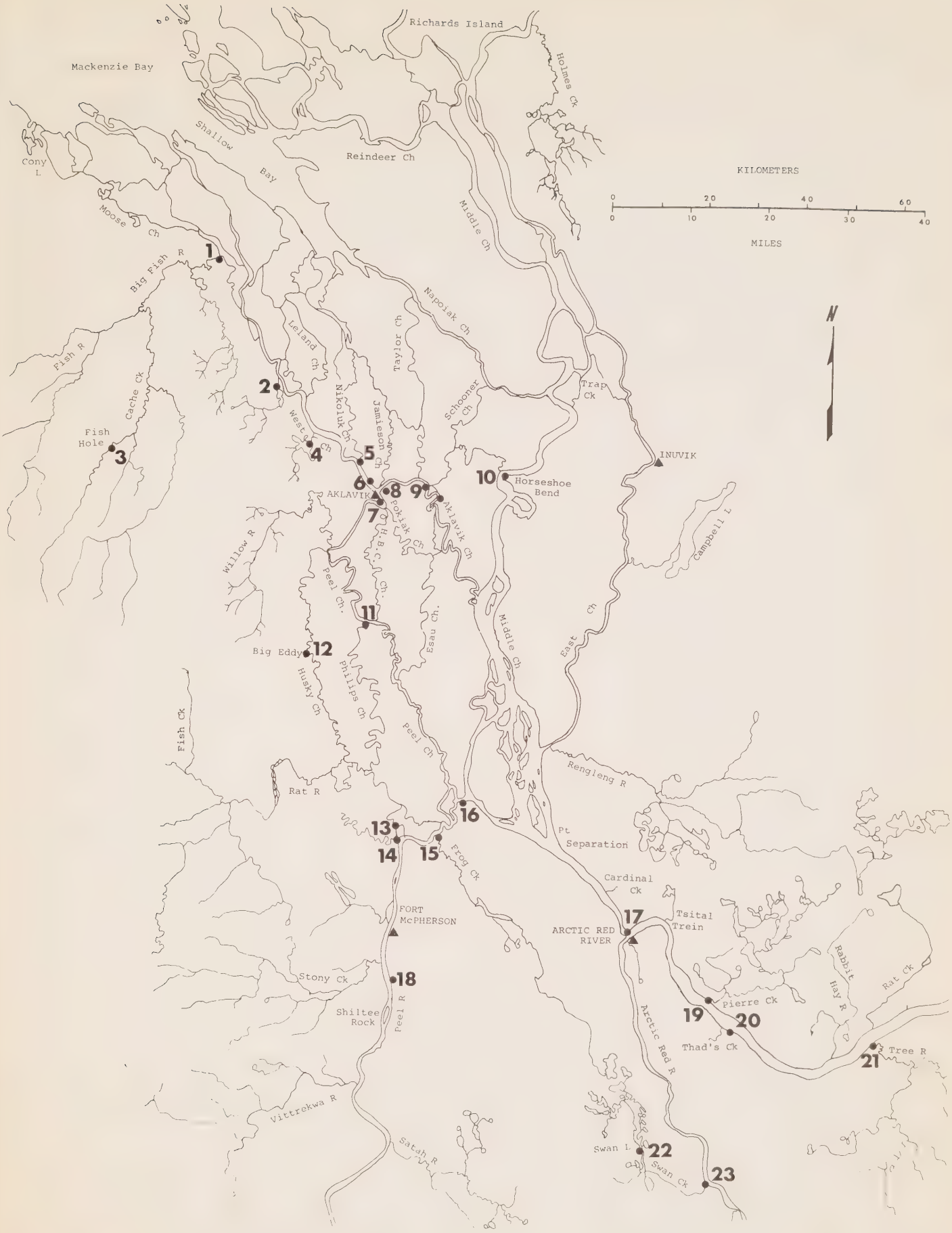

Fig. 41. Aklavik, Arctic Red River and Fort McPherson study areas showing pertinent tagging and recovery locations.

Forty Arctic char were tagged at "Big Eddy" on the Husky Channel (Fig. 41; loc. 12) between August 29 and September 1. One fish reached the lower Rat River 45 miles away within two weeks while another had moved in the opposite direction and was caught near Aklavik five days later.

Inconnu

Only two inconnu were recaptured from fish tagged in the delta area. One fish tagged at Big Fish River (Fig. 41; loc. 1) was recaptured in the Peel Channel (loc. 7) in late October, 88.5 km (55 miles) upstream. The second fish, caught in Arctic Red River, had moved 61.1 km (38 miles) in 9 days from Frog Creek (loc. 15).

Twenty tag returns from the Arctic Red River base showed considerable movement. Nine of these fish, released in the vicinity of Arctic Red River (loc. 17) between July 26 and August 29, had reached the Fort Good Hope area between August 18 and October 13. Two fish tagged at Pierre Creek (loc. 19) travelled 530.1 km (330 miles) to Norman Wells between July 28 and September 14. One fish released at the mouth of the Peel in July had moved 61.1 km (38 miles) up the Peel within a month.

Humpback Whitefish

Two fish released in late August at the mouth of Big Fish River (Fig. 41; loc. 1) were found upstream in the Peel River nine to 13 days later, the distance travelled being 119.0 km (74 miles). From a run of fish tagged at Horseshoe Bend (loc. 10) on September 13-15, one was recovered at Arctic Red River after 41 days while another was recaptured at Aklavik on November 14. Tagging of humpback whitefish in late October in the Aklavik Channel (loc. 9) produced three tag returns downstream in the West Channel (loc. 5 and 6).

Tag returns from the Arctic Red River base showed downstream movement. Five fish caught at Arctic Red River (loc. 17) during the fall had been tagged upstream in August at Tree River (loc. 21) and Thad's Creek (loc. 20). Two fish from location 20 were caught in the Peel River eight to 63 days after release. Of fish tagged in August at Arctic Red River and Tree River, two were recaptured at Horseshoe Bend (October 4-8), two at Aklavik (October 4-8) and three in the Aklavik Channel in mid-November.

Broad Whitefish

Fifteen fish released at Horseshoe Bend (Fig. 41; loc. 10) on September 13-14 were recaptured at Arctic Red River on November 8-11, 104.6 km (65 miles) upstream. Fourteen fish recaptured near the town of Arctic Red River had been released in July and August at upstream locations such as Pierre Creek (loc. 19), Thad's Creek (loc. 20), and Tree River (loc. 21). Several other fish tagged at these locations were recovered in the Peel River (loc. 16) in September. Two fish had travelled as far upstream as Fort Good Hope, 301.5 km (188 miles) within 21 to 26 days after their release at Arctic Red River in early September. Nine fish released at Arctic Red River in late October were recovered in the delta four to 20 days later.

Least Cisco

Most least cisco returns were recovered close to the release point, within a day by domestic fishermen. Two of the fish tagged in the Peel River during September were recaptured downstream. One of these was caught in the Husky Channel (Fig. 41; loc 13), the day after its release near Eight Mile Creek (loc. 18).

Arctic Cisco

Almost all Arctic cisco tag returns in the Aklavik area came from local people fishing in the immediate vicinity of the release site (Fig. 41; loc. 7). Two fish, released in mid-August in the Peel River below Fort McPherson, were recaptured near Aklavik 30 to 50 days later.

Of fish tagged in the first week of August at Arctic Red River (loc. 17), two were caught at Aklavik after two to three months, while a third was recaptured at the mouth of the Peel River after only a few days.

Northern Pike

About 50 per cent of northern pike recaptured by the Aklavik base had shown minor movement from zero to 90 days later. However, three pike did move from 16.1 to 49.9 km (10-31 miles).

In the Arctic Red River area, most pike did not show significant movement from the release point. Two fish, tagged

at the mouth of the Rat River (Fig. 41; loc. 14) on August 9, were found 69.2 km (43 miles) downstream in the delta, September 12 and November 1.

Burbot

Tag returns, which came only from the Aklavik base, were primarily from fish tagged at location 8 and near location 9 (Fig. 41). Sixty-three returns came from fish caught at the same release point, four to 59 days later.

Six fish from the vicinity of location 9 travelled 19.3 to 24.1 km (12 to 15 miles) up or down the Aklavik Channel. Another five fish tagged at location 8 in early September moved in various directions. The furthest distance travelled was 90.0 km (56 miles) to the junction of Peel and Phillips channels (loc. 11) in 30 days.

8.4.3.2 Norman Wells

Arctic Grayling

In late June, 861 grayling were tagged in Three Day Lake at the outflow of Stewart Creek (Fig. 42; loc. 1). A post-spawning movement occurred down Stewart Creek after June 15 and tag recoveries provided some insight on their dispersal.

Two tag returns indicated that the 12.9 km (8 mile) trip to the creek's confluence with the Mackenzie River (loc. 2) may take at least 6 days. Several tags were recovered upstream on the Mackenzie within a month at location 3 and 4. Three more fish had moved up the Great Bear River, the greatest distance travelled being 159.0 km (99 miles) to location 7.

Other Species

The few tag returns for other species generally showed little movement. Two fish were recovered outside the Norman Wells study area by domestic fishermen in Fort Good Hope. One of these, a white sucker tagged at Norman Wells on July 27 was caught 67 days later, 185.0 km (115 miles) downstream. The other, an Arctic cisco, released at Bluefish Creek (loc. 3) on August 2, travelled 257.0 km (100 miles) downstream in 30 days.

Fig. 42. Norman Wells study areas showing pertinent tagging and recovery locations.

8.4.3.3 Fort Simpson

Northern pike, which comprised almost half of the fish tagged and released in the Fort Simpson area (Fig. 43), were found at 48 of 57 tagging locations. Sixteen per cent of the tagged pike were recaptured.

Analysis of returns from individual tagging locations revealed two general types of locations based on the movement of pike. The first type, which included Roundup Creek, Blue Fish Creek, Rabbitskin River and the Spence River, had fish that showed little movement during the summer. Spence River had the most significant returns of any location (22 of 68 released pike). Twenty of these were recaptured within a mile of the release point between one and 55 days later.

The second general location type consisted of small back eddies or river mouths where released pike were captured considerable distances away. An example was Manners Creek, where five of 10 released fish were recaptured. Of these five, four fish were recaptured 31 to 93 km (19 to 58 miles) away, between seven and 106 days later.

Fig. 43. Fort Simpson study areas showing pertinent tagging and recovery locations.

8.5 Spawning and Nursery Areas

Results presented in this section include spawning areas and primary nursery areas of major fish species, located during 1971 and 1972. Locations are presented in Figure 7. A stream was classified as a known spawning area if fry were captured upstream from the mouth, if both ripe and spent adults were abundant simultaneously, or if fish were observed spawning. A stream was classified as a suspected spawning area if fry or ripe adults were present in significant numbers. An area was considered a major nursery area if fry were numerous. In several instances, juveniles were noted in streams not listed in the following sections. It is not meant here to subordinate the importance of these streams to the resource. Rather, it is a list of known streams in which substantial numbers of fish were found throughout the field season or where numbers far exceeded those of other systems in the area at the time of sampling. Spawning and nursery areas described are limited primarily to those within base camp areas, where regular sampling occurred. In areas between the bases, limited sampling by the synoptic crew enabled identification of only a few of the many potential spawning and nursery areas.

8.5.1 Arctic Grayling

Known spawning areas include Rat R., Swan Cr. and Swan Lake, Tree R., Three Day Lake and inlet streams, Porcupine R., Martin R., Rabbitskin R., Spence R., Trout R., and five unnamed tributaries in the vicinity of Fort Simpson. An unnamed tributary at Fort Providence was identified as a spawning area for grayling by Bishop (1971). Suspected spawning areas included Hare Indian R., Trail R., Harris R., Blue Fish Cr., Jean-Marie Cr., and two unnamed tributaries in the vicinity of Fort Simpson.

Spawning occurred following ice breakup on the rivers during late May and early June. Water temperatures during the

spawning period ranged from 7-15 C (45-59 F).

Major nursery areas were Big Fish R., Cache Cr., Willow R., Rat R., Tsital Trein Cr., Tree R., Hare Indian R., Donnelly R., Mountain R., Bluefish Cr., St. Charles Cr., Porcupine R., Trail R., Rabbitskin R. and Trout River.

8.5.2 Lake Trout

No spawning areas were located. Great Bear River was the only nursery area located.

8.5.3 Arctic Char

Known spawning areas were Cache Cr. and Fish Cr. During August and September, 1971, char were observed spawning at Fish Cr. at water temperatures of 4-8 C (39-46 F). Major nursery areas were Cache Cr. and tributaries as well as Fish Cr.

8.5.4 Inconnu

No spawning areas of inconnu were located. Tributaries of the Peel and Arctic Red rivers are suspected spawning areas. A few inconnu fry were captured in the Rengleng R., Peel R., Mackenzie R. at Arctic Red River, and Pierre and Oscar creeks.

8.5.5 Broad and Humpback Whitefish

Back eddies of the Mackenzie River in the vicinity of Arctic Red River appeared to be spawning areas for both species. Ripe and spent humpback whitefish were most abundant during early October at a water temperature of 1.5 C (35 F), while numbers of ripe and spent broad whitefish peaked during late October at 0 C (32 F).

Because of identification difficulties with whitefish fry, nursery areas for both species have been combined. Important nursery areas included Rengleng R., Frog Cr., Tsital Trein Cr., Travaillant R., Carcajou R., Oscar Cr., Loon Cr., Stewart Cr., Prohibition Cr., Vermilion Cr., Little Bear R., Blue Fish Cr., Martin R., Harris R., Rabbitskin R. and Spence R. Back eddies of the Mackenzie were also important nursery areas, particularly at Point Separation, and at Slater R.

8.5.6 Least Cisco

No definite spawning areas were located. Suspected spawning areas included Peel Channel, Husky Channel, Peel R., and Mackenzie R. in the vicinity of Arctic Red River. A spawning run of ripe fish was noted during late September and early October in these areas. Water temperatures during this period ranged from 1-1.5 C (34-35 F).

8.5.7 Arctic Cisco

No spawning areas were located. Suspected spawning areas were tributaries of the Arctic Red, Peel, Mountain and Great Bear rivers. Mature fish were abundant at the mouths of these rivers during July and August. A downstream migration of spent cisco was noted in the Peel Channel at Aklavik during early October. Some spent cisco were caught at the mouth of the Arctic Red River during this period.

Because of identification difficulties with cisco fry, nursery areas for both species of cisco are combined. Major nursery areas included Peel Channel at Aklavik, Peel R. and seven tributaries, Frog Cr. and one tributary, Stony Cr., Satah R., Mackenzie R. at Point Separation, Vermilion Cr. and Spence R.

8.5.8 Northern Pike

Known spawning areas included Travaillant Lake, Rabbitskin R., Spence R., Jean-Marie Cr., and Trout Lake. In both Travaillant and Trout lakes, large numbers of ripe and spent pike were observed in the lake shallows.

Suspected spawning areas were Rengleng R., Swan Cr., Dzien Die Cr., Rabbit Hay R., an unnamed tributary draining Rat Lake, Stick Cr., Trail R., Martin R., Harris R., Blue Fish Cr., and the Mackenzie R. in the vicinity of Fort Simpson.

Spawning occurred after ice breakup on the rivers, from late May in the southern Mackenzie valley to early July in the northern valley. Water temperatures during the spawning period ranged from 7-16 C (45-61 F).

Major nursery areas for pike were the junction of Taylor and Aklavik channels, Trail R., an unnamed tributary at Fort Simpson, Harris R., Rabbitskin R., Spence R., and Trout R.

8.5.9 Yellow Walleye

Known spawning areas were Island R. and Jean-Marie Cr. Suspected spawning areas were Rengleng R., Pierre Cr., Oscar Cr., Stewart Cr., an unnamed tributary at Norman Wells, Vermilion Cr., Slater R., Little Bear R., Trail R., an unnamed tributary near Martin R., Martin R., Harris R., Rabbitskin R., Spence R. and Trout R.

Spawning occurred after ice breakup on the rivers during late May, at water temperatures ranging from 7-8 C (45-46 F).

Major nursery areas included Tsintu R., Mackenzie R. and an unnamed tributary at Norman Wells, Vermilion Cr., Slater R.,

Little Bear R., Trail R., Harris R., Spence R., Jean-Marie Cr., and Trout Lake.

8.5.10 Burbot

Known spawning areas were Big Fish R., Tree R. and Martin R. Suspected spawning areas were Rengleng R., Slater R., and an unnamed tributary 21 miles north of Fort Simpson.

Major nursery areas were Big Fish R., Tree R., Slater R., and Jean-Marie Cr.

8.5.11 Longnose Sucker

Known spawning areas were Swan Cr., Nagle Cr., Pierre Cr., Rabbit Hay R., Tree R., Three Day Lake or tributaries, Trail R., Harris R., Manners Cr., Rabbitskin R., Spence R., Jean-Marie Cr., Trout R., and Island R. Suspected spawning areas included Rengleng R., Frog Cr., Stony Cr., an unnamed tributary 6 miles north of Arctic Red River, Tsital Trein Cr., Dzien Die Cr., an unnamed tributary draining Rat Lake, Loon R., Carcajou R., Trapper Cr., Oscar Cr., Prohibition Cr., Vermilion Cr., an unnamed tributary at Norman Wells, Slater Cr., Little Bear R., Bluefish Cr., Brackett R., Martin R., and three unnamed tributaries in the vicinity of Fort Simpson.

Spawning occurred after ice breakup on the rivers, from late May in the southern Mackenzie valley to mid-June in the northern valley, at water temperatures of 8-16 C (46-61 F).

Major nursery areas included Rengleng R., Stony Cr., Tree R., Hare Indian R., Carcajou R., Oscar Cr., Vermilion Cr., Little Bear R., St. Charles R., Trail R., an unnamed tributary 25 miles north of Fort Simpson, Harris R., Matou R., Blackstone R., Grainger R., Rabbitskin R., Jean-Marie Cr., Trout R., and Mackenzie R. in the vicinity of Fort Simpson.

9. DISCUSSION

9.1 Limitation of Methods

Gill Nets

Variations in the river conditions at each base made it impossible to standardize sampling procedures. Therefore the validity of comparisons between index stations or bases is reduced. In addition, only a small portion of the Mackenzie itself could be sampled at any time or station, and it is conceivable that major fish movements were not detected.

The two week interval between consecutive sampling of an index station may have been too long. A spawning or post-spawning run of fish may have moved past that station in the interim.

Seines

Beach seines were effective under most situations for capturing small fish. However, the mesh size limited sampling for very small specimens. Seines also have little value in collecting fish from debris laden or rocky bottomed areas, or from riffle habitats.

Tagging

Several factors may have influenced the success of the fish tagging program. The following are noteworthy:

1. Sensitivity of different species to tagging.

2. Mortality of tagged fish after release due to injury, infection with parasites or disease, or attack from predators.

3. Incomplete reporting or non-return of tags.

4. Loss of tags after release.

5. Tagging too small a sample of a particular species.

6. Immigration.

7. Emigration.

8. A non-uniform mixing and distribution of tagged and untagged fish.

Age and Growth Analysis

Age determinations from scales appeared to be satisfactory for plotting reliable growth curves for most fish species. Scales with more than 10 annuli may have been under-aged due to crowding of annuli near the scale periphery.

Mean lengths shown for younger fish may be slightly higher than that of the actual stream population due to gear selectivity. Fish used for aging purposes were collected throughout the growing season. Thus, in a particular age group, one fish could have no growth, whereas another could have a full season's growth. This possibility resulted in a larger length range and larger standard deviation than present in the stream populations. Other errors and variations may be contributed to counting false annuli, sex differences, year class strength and the movement of fish from areas having diverse growth rates.

Stomach Analysis

Capture of fish by gill nets imposes certain limitations on stomach content interpretation. Fish often remained in the net for several hours during which digestion of stomach contents continued. Regurgitation, as a result of stress, may have occurred. Fish with piscivorous feeding habits, such as pike, sometimes fed upon fish caught in gill nets before becoming entangled themselves. The stomach contents of such fish would not reflect normal food habits.

Seine Analysis

Few suitable keys are available for the

identification of young-of-the-year fish. Many specimens could only be classified to genus or family. Seine catches were preserved in five to 10 per cent formalin. This causes dehydration with a subsequent reduction in fish length and increase in weight.

Population Estimates

Population estimates from tag return data were made with the assumption that factors modifying the population size, as mentioned previously, were minimal. However, all these factors invariably become involved. Consequently, estimates were made only in those cases where tag returns were sufficient, total catch data was available, and where conditions existed so that the spatial and temporal separateness of a specific population or unique group of fish could be identified.

In any attempt to estimate accurately the population of fish in a specific area, there exists the additional possibility that the data used was collected in a biased manner. The bias in the tagging program described was one of gear and fish size selectivity. Gill nets and trap nets were used to catch fish large enough to be tagged. Consequently, population estimates were made for "catchable size" fish.

9.2 Distribution of Species

Distribution ranges, as indicated in McPhail and Lindsey (1970), were extended under the present study for the following species: least cisco, lake cisco, mountain whitefish, longnose dace, northern redbelly dace, brook stickleback, slimy sculpin and goldeye.

Least cisco distribution was extended southward from Fort Simpson to Spence River (Fig. 17).

Lake cisco range was extended from Great Bear River northward to Pierre Creek (Fig. 18). A single specimen was also taken in the Liard system at Manner's Creek.

Mountain whitefish were recorded in the Fort Simpson and Norman Wells areas (Fig. 15). Single juveniles were caught in seines at the mouths of Oscar Creek, Canyon Creek and Brackett River. Three juveniles were caught in Big Smith Creek. A total of 75 adults and juveniles were caught in the Fort Simpson area.

Longnose dace were found in a number of tributaries from Trout River to the delta (Fig. 24). Longnose dace occupy rocky sections of tributaries, hence were not susceptible to most sampling gear used. It is possible that the distribution and abundance is greater than the data indicates.

Several specimens of northern redbelly dace were found in the Arctic Red River and Norman Wells areas (Fig. 25).

Brook stickleback range was extended from Great Bear Lake northward to the Norman Wells and Arctic Red River areas (Fig. 32).

Slimy sculpins were caught in seines in most sampled tributaries of the Mackenzie River (Fig. 34). Specimens were usually taken at the confluence of the tributary and the Mackenzie River,

although several specimens were taken in the main stem Mackenzie River in the Norman Wells and Arctic Red River areas.

A single specimen of goldeye was caught at Point Separation on the Mackenzie River (Fig. 27). Two specimens were recorded near Fort Norman. A total of 44 specimens were caught in the Fort Simpson area primarily at the mouths of the Martin and Liard rivers.

9.3 Migration Routes and Timing

9.3.1 Arctic Grayling

The life cycle of Arctic grayling is complicated and aspects of its seasonal movements, as yet not fully delineated, may vary for different populations in the Mackenzie valley.

In the Arctic Red River region, grayling occurred in the Mackenzie and larger tributaries only during June and early July. The scarcity of grayling at index stations (Fig. 38) during the summer may be explained in part by the behavior of Swan Lake-Swan Creek grayling. The 1972 spawning population moved upstream into the lake during the first two weeks of June and, based strictly on tag returns, appeared to remain in the lake-creek drainage during the summer.

Summer grayling movements further south differed in that spent fish moved back into the Mackenzie in late June. Grayling occurred in all index fishing cycles in the Norman Wells and Fort Simpson areas (Fig. 39 and 40). Tag returns indicated that some fish tagged at Three Day Lake contributed to the summer population in the Great Bear River system.

Data indicate summer resident adult and juvenile grayling move out of some small tributaries during the fall to overwintering areas.

9.3.2 Arctic Char

During the 1971 field season, a spawning run of Arctic char was observed in Fish Creek, a tributary of Rat River, during August. During 1972, Arctic char migrated from the Beaufort Sea and entered the lower part of the Big Fish River in mid-August,

reaching "Fish Hole" on Cache Creek during late September and October (Fig. 41; loc. 3). "Fish Hole" is reported to be the only suitable spawning area in the Big Fish River system wherein the population resides during winter. An Arctic char run was detected at "Big Eddy" on the Husky Channel during late August and early September.

Mature fish of the anadromous form of Arctic char migrate to sea at breakup; however, observations have yet to be made as to the actual date when this occurs.

9.3.3 Inconnu

Most successful catches of inconnu occurred in July (Fig. 37 and 38) in the north, early August in Norman Wells (Fig. 39) and late August in Fort Simpson (Fig. 40). Upstream migrations occur primarily in the main stem of the Mackenzie River, Arctic Red River, and the Peel River.

While tag returns did not show a post-spawning movement, the presence of spent fish in catches made during the first two weeks of October near the town of Arctic Red River corresponded with local reports of an annual downstream run out of Arctic Red River. Some fish caught in the Peel and Mackenzie River in October and November were spent and appeared emaciated. The downstream run in the Peel River, according to residents, is significant and occurs after freeze-up in early October.

Information on the actual times and secondary routes of inconnu movements in the upper Mackenzie River is still lacking. However, the first appearance of ripe fish in the Norman Wells area occurred by August 15. The absence of ripe fish in the Fort Simpson area suggests that the migration does not reach the upper Mackenzie River.

9.3.4 Humpback Whitefish

By mid-September, an upstream run of humpback whitefish appeared along the main stem of the Mackenzie River and in major delta channels. A heavy concentration of ripe fish was prevalent near Arctic Red River in the first week of October. There appeared to be no significant run of humpback whitefish up the Peel River during fall.

Domestic catches and tag returns indicated spent humpback whitefish moved downstream from the Arctic Red River area, past the Aklavik area in late October and early November. Data were insufficient to indicate clearly the movement of humpback whitefish in either the Norman Wells or Fort Simpson areas.

9.3.5 Broad Whitefish

Broad whitefish moved upstream during late August as indicated in Figures 37 and 38. Field observations and tag recapture data indicated the run peaked during September and October. Fish were abundant near Arctic Red River between October 16 and November 10 with peak catches occurring November 3-5. Rapid decrease in total catches after this date coincided with a greater percentage of spent fish per catch.

Tag returns from the delta during the first two weeks of November indicated that the downstream post-spawning migration began during this period. It appeared that the Middle Channel was utilized by the greatest portion of the broad whitefish run. Significant numbers of fish were also found in the Aklavik and West channels during the second week of November.

9.3.6 Least Cisco

Least cisco were common in the lower

Mackenzie River throughout the season. Catches increased during the last two weeks of August (Fig. 37) when an upstream migration occurred through the delta. Catches began to increase in late August at Arctic Red River (Fig. 38), and peaked around October 15. The sporadic nature of catches suggested that this species may travel in large schools. Suspected migration routes include the Mackenzie and Peel rivers. However only small numbers of least cisco appeared in the Peel River domestic catch, probably due to the use of gill nets no smaller than 8.9 cm (3.5 inches). No information was obtained this year on the downstream movements of least cisco.

9.3.7 Arctic Cisco

Crews at Aklavik and Arctic Red River observed an upstream movement of Arctic cisco during the summer, which peaked during the first two weeks of August at Arctic Red River (Fig. 38). Significant numbers of ripe Arctic cisco appeared in Norman Wells on August 2 on their way to suspected spawning grounds in the Great Bear River and its tributaries. In the Peel River, an upstream run peaked during August at the mouth and during September at a location 72 km (45 miles) upstream.

Post-spawning runs down the Arctic Red River, Peel River and Peel Channel occurred between October 6 and 26. Fish at this time were spent and noticeably emaciated.

9.3.8 Northern Pike

Northern pike moved out of delta lakes and creeks between mid-August and freeze-up in September and subsequently appeared to concentrate at creek mouths during October and November.

Recaptures at Fort Simpson showed that northern pike dispersed randomly after spawning. Many fish became residents in shallow, weedy stream mouths such as the Spence and Rabbitskin rivers.

9.3.9 Burbot

Tagged burbot showed little movement from release points in the delta. Significant numbers were caught in trap nets in the fall, between mid-August and late September, as they moved out of delta lakes and creeks. Feeding burbot were congregated at creek mouths during October and November.

Local fishermen have observed that by late October burbot move gradually upstream through the delta, presumably to upstream spawning areas. However, this movement has yet to be confirmed.

9.4 Spawning Areas and Times

9.4.1 Arctic Grayling

In the current study, spawning generally occurred in clear tributaries of the Mackenzie River following ice breakup at water temperatures of 7-15 C (45-59 F). Grayling spawned during breakup at water temperatures of 8-10 C (46-50 F) in a tributary of the Mackenzie River studied by Bishop (1971). Although grayling generally spawn over rocks or gravel (Rawson, 1950) spawning will occur over a variety of substrates (Reed, 1964).

9.4.2 Lake Trout

No spawning areas were located in the current study. Spawning usually occurs over rocky shoals in lakes but river-spawning populations also exist (Loftus, 1958).

9.4.3 Arctic Char

At "Fish Hole", Cache Creek, char appeared to spawn over fine gravel in pools below rapids, during October, at water temperatures of 0-3 C (32-37 F). In Fish Creek, spawning occurred in a similar habitat during August at a water temperature of 8 C (46 F). McPhail and Lindsey (1970) also reported that char spawn over gravel in pools below rapids during autumn.

9.4.4 Inconnu

No spawning areas were located. Tributaries of the Peel and Arctic Red rivers are suspected spawning areas. Inconnu spawned over gravel in clear tributaries of the Yukon River during late September and early October at water temperatures of 3-5 C (37-41 F) (Alt, 1969).

9.4.5 Humpback Whitefish

Catches of both ripe and spent fish peaked during early October in back eddies of the Mackenzie River near Arctic Red River, indicating possible spawning areas. In Great Slave Lake, spawning occurred from mid-September to mid-October over rocky shoals or in the shallows of tributaries (McPhail and Lindsey, 1970).

9.4.6 Broad Whitefish

Many ripe adults were recaptured at the mouth of the Arctic Red River, within a few days of tagging, indicating holding and possible spawning. Catches of ripe and spent fish peaked after freeze-up during late October. This is considerably later than the spawning period of August reported by Wynne-Edwards (1952) for broad whitefish in the Mackenzie River. However, it corresponds with the spawning period reported by Berg (1948-49) for broad whitefish in Siberia.

9.4.7 Least Cisco

No spawning areas were located. Runs of ripe fish were noted in the Peel and Husky channels, Peel R. and Mackenzie R. during late September and early October at water temperatures of 1-1.5 C (34-35 F). In Alaska, spawning was observed in swift, clear water over gravel with some sand at 0-2 C (32-36 F) (Alt, pers. comm., 1971). In Siberia, least cisco spawned under the ice, over sand and gravel in the lower reaches of rivers (Berg, 1948-49).

9.4.8 Arctic Cisco

No spawning areas were located. Large numbers of mature cisco ascended the Peel and Arctic Red rivers during summer as previously reported by Wynne-Edwards (1952).

In Siberia, spawning occurred over gravel in clear tributaries of major rivers during late summer and early autumn (Berg, 1948-49). A downstream migration of spent cisco was noted in the Peel Channel at Aklavik during early October, similar to that described by Wynne-Edwards (1952) for the Mackenzie River.

9.4.9 Northern Pike

Tributary mouths and lake shallows with flooded vegetation were the most important spawning areas in the current study. Spawning occurred after ice breakup, from late May to early July at water temperatures of 7-16 C (45-61 F). In contrast, Wisconsin pike spawned during breakup at a water temperature of 4 C (39 F). Spawning occurred in shallow water over flooded emergent vegetation (Threinen et al., 1966).

9.4.10 Yellow Walleye

Spawning in the Island River and Jean-Marie Creek occurred after ice breakup during late May at water temperatures of 7-8 C (45-46 F). In Lac la Ronge, Saskatchewan, walleye spawned after breakup at water temperatures of 7.7-10 (46-50 F) (Rawson, 1957). Similarly, Wisconsin walleye spawned after breakup at water temperatures of 8.9-10 C (48-50 F) (Niemuth et al., 1959).

9.4.11 Burbot

Known spawning areas were located in clear tributary streams. Spawning period for the Mackenzie River system is unknown. Minnesota burbot spawned during early February at a water temperature of 1.5 C (35 F) (Cahn, 1936). In Heming Lake, Manitoba, male burbot were ripe during late February at a bottom temperature of 3.9 C (39 F), while females matured later (Lawler, 1963). Spawning usually occurs over sand or

gravel in streams or lake shallows in 0.3-1.3 m (1.0-4.3 ft) of water (McPhail and Lindsey, 1970).

9.4.12 Longnose Sucker

Spawning generally occurred in clear tributaries of the Mackenzie River after ice breakup, from late May to mid-June, at water temperatures of 8-16 C (46-61 F). Similarly, Great Slave Lake suckers spawned from ice breakup in May to June 15 at water temperatures less than 15 C (59 F) (Harris, 1962). Spawning occurs in tributary streams or lake shallows (McPhail and Lindsey, 1970). In the Kolyma River, Siberia, longnose suckers spawned after ice breakup in June over gravel in swift river sections (Nikolsky, 1961).

10. CONCLUSIONS

10.1 Migration Routes and Times

Between mid-August and early October, major upstream spawning migrations of inconnu, humpback whitefish, broad whitefish and least cisco occur through the delta channels. These species proceed to spawning areas in the Peel River, Arctic Red River and other upstream tributaries of the Mackenzie River. Arctic cisco movements start as early as late July and, similar to inconnu, some fish may migrate as far as Norman Wells, approximately 700 km (435 miles) up the Mackenzie River. Post-spawning migrations towards the delta occur in October and November.

Arctic char enter the delta by August. The spawning population of Big Fish River reaches the river mouth by mid-August and moves upstream to spawning grounds during September and October.

Northern pike, longnose suckers, yellow walleye and Arctic grayling, migrate up suitable streams to spawn immediately after ice breakup (late May to early June). While some Arctic grayling populations remain in a lake-stream system during the summer, many post-spawning adults migrate to the main stem of the Mackenzie in late June. Summer resident adult and juvenile grayling move out of some small tributaries during the fall, to overwintering areas.

10.2 Spawning and Nursery Areas and Times

Arctic grayling, yellow walleye, northern pike and longnose sucker spawn shortly after spring breakup on tributary streams (mid-May to mid-June). Inconnu, humpback whitefish, broad whitefish, Arctic cisco, least cisco, and Arctic char have spawning periods ranging from early September to early November.

Clear tributaries are the most important spawning and nursery areas for yellow walleye, Arctic grayling, Arctic char, and burbot. Spawning and nursery areas of whitefish, cisco, longnose sucker and northern pike range from clear to turbid. Tributary mouths and large back eddies of the Mackenzie River also appear to be significant nursery areas.

10.3 Fish Species Resilience

The ability of a fish population to withstand environmental disruption varies with the species, size and stability of the population, and the availability of suitable habitat. Brief sensitivity descriptions for Mackenzie valley fish species are given below.

Most northern fish species utilize four general habitat types, namely, spawning, rearing, summer feeding and overwintering habitats. Present data indicate that the main stems of large rivers such as the Mackenzie, Peel or Liard, serve mainly as migration routes. Spawning, rearing and summer feeding habitats are usually found in small tributaries or the back eddies of large streams.

Non-migratory species appear to overwinter in deep tributary pools, large river systems, or suitable connecting lakes.

Tag returns from grayling in the Norman Wells area indicated that two or more river systems may be used by different life history phases of the same population; such as, for spawning, summer feeding or overwintering. It is therefore apparent that safeguards required for the protection of a given population may have to consider several river systems. Provided that the disturbance is limited and of short duration, the aquatic environment will likely return to a relatively stable state. Although some fish loss will occur, the area will eventually be repopulated by the remaining segment of the population, or by fish from the surrounding area.

10.3.1 Arctic Grayling

With the possible exception of Arctic char, Arctic grayling probably have the least resilience to environmental disruption. Growth rates of this species are slow and catches of adults in the Mackenzie system were spread over

relatively few age classes. Thus a significant reduction in numbers of any age class would require a long recovery period even if no further environmental disruptions or stress occurred. The dependence of grayling on terrestrial and aquatic insects for food also makes it particularly vulnerable to insecticide sprays and chemical spills which could reduce or contaminate these sources of food.

10.3.2 Arctic Char

At least one life history stage of Arctic char is present in a stream system at all times of the year. It is therefore particularly vulnerable to silt or chemical pollution throughout the year. Char were found in only a few areas of the Mackenzie valley, and, where significant numbers were present, a substantial domestic fishery existed. Further reduction in numbers, resulting from construction activities or from sport fishing, could be detrimental to the char populations.

10.3.3 Inconnu

Because inconnu are unique to northwestern North America and are significant to the domestic fishery, their preservation is important. A wide age class distribution makes this species, theoretically, better able to withstand an isolated short term environmental disruption. However, since inconnu require clear water and silt-free gravel for spawning, and do not feed during spawning migrations, they are vulnerable to physical environmental disruptions and stress.

10.3.4 Humpback Whitefish

This species is probably quite

resilient because of a wide age class distribution, a tolerance of a wide range of turbidity and high numbers in the system. Limited physical disruptions of a controlled type are likely to be tolerated by this fish. Since it depends on benthic organisms for food, particularly in the delta region, it would be adversely affected by any chemical contamination of its environment.

10.3.5 Broad Whitefish

Resilience of this species is probably similar to that of the humpback whitefish. Limited feeding occurs during spawning migrations which suggests that added stress at this point in the life cycle could be harmful.

10.3.6 Arctic and Least Cisco

These species have a good potential for commercial fishery development but are quite vulnerable to environmental disruptions. Since the bulk of the spawning migrations are made up of only three to four age classes, a major reduction of these age groups would mean a long recovery time for the population. The tendency of Arctic and least cisco to congregate in small back eddies, and the relatively uniform size of the spawning population, make them particularly susceptible to overfishing with nets. Since neither species apparently feeds during spawning migrations they are particularly vulnerable to added stress at that time.

10.3.7 Northern Pike, Yellow Walleye, Longnose and White Sucker, Lake and Flathead Chub, Trout-perch and Burbot

Most of these species have high

resilience because of wide habitat tolerance, high numbers and extensive distribution. Trout-perch, suckers and chub are forage fish and their importance in the food chain of inconnu, lake trout, pike and walleye should not be overlooked. Modest reduction in numbers of these species would probably be compensated by repopulation from other areas, provided environmental conditions returned to normal.

10.3.8 Lake Trout, Dolly Varden, Chum Salmon, Round and Mountain Whitefish, Lake Cisco, Longnose and Redbelly Dace, Spottail and Emerald Shiner, Brook and Ninespine Stickleback, Slimy and Spoonhead Sculpin, Boreal and Pond Smelt, Goldeye and Arctic Lamprey.

These species were not caught in sufficient numbers to warrant speculation on their resilience. However, because they do appear to exist in small numbers in the areas sampled, the local environment is probably not suitable to support larger numbers. If recommendations for protection of the abundant species of the Mackenzie valley are followed, these species will be adequately protected.

11. IMPLICATIONS AND RECOMMENDATIONS

11.1 Recommendations Related Specifically to Pipeline Construction and Operation

11.1.1 Stream Systems where Fish Resources are Biologically Sensitive to Pipeline Construction

Sufficient data are now available to enable compilation of a tentative list of stream systems in which, in the opinion of the Fisheries Service, the fish resources are sensitive to construction activities in any form. Sensitivity has been based primarily on the biological fragility of the resource as well as the significance of fish populations to existing domestic fisheries.

It is recommended that the following systems be avoided in any pipeline routing. Should avoidance be deemed impossible, firm restrictions on construction scheduling, stream crossing techniques and silt retention methods must be imposed if the impact on the resource is to be minimized.

Mackenzie River (Delta)

Preliminary data indicate the delta to be extremely productive. It is an important feeding and nursery area for several species, particularly coregonids. Migratory fish populations, including Arctic char, broad whitefish, humpback whitefish, Arctic cisco, least cisco and inconnu, must negotiate the delta on upstream and downstream migrations.

A substantial domestic fishery as well as an experimental commercial fishery presently exist in the delta. These and domestic fisheries upstream could

be adversely affected by major disruptions to fish populations or migrations.

Big Fish River

This system contains an Arctic char population estimated in 1972 at between 12,000 and 17,000 fish. A substantial fall fishery, conducted primarily by Aklavik residents, exerts considerable pressure on this resource. At least one phase of the known life history of Arctic char is present in a system at all times and would be vulnerable to disruption. In our opinion, a significant reduction in this population resulting from construction activities would have serious social and economic effects and could not be tolerated.

Rat River

The Rat River system contains spawning grounds of one of the two known Arctic char populations in the Mackenzie River system. In addition to being biologically sensitive, this population is fished domestically by the residents of Aklavik, Arctic Red River and Fort McPherson.

Jean-Marie Creek

Jean-Marie Creek contains the spawning grounds of large populations of yellow walleye and Arctic grayling. These species are heavily fished by the natives of Jean-Marie village and could not tolerate further disturbance.

Trout River

Trout River supports significant spawning runs of Arctic grayling, yellow walleye and whitefish, and is heavily used

as a nursery area. It is one of the few systems in the area with sport fishing and recreation potential.

Additional river systems whose fish resources, pending further investigation, may be considered sensitive to pipeline construction include:

Island River	Horn River
Hare Indian River	Stewart Creek
River between two Mountains	Tree River
	Swan Creek
Kakisa River	Donnelly River
Loon River	Vermilion Creek
Spence River	Peel River
Great Bear River	Arctic Red River (mouth)

11.1.2 Seasonal Times at which Fish Resources are Biologically Sensitive to Northern Pipeline Construction

Fish migrations, fish spawning and egg incubation periods are biologically sensitive times for in-stream construction activities. Primary reasons for concern in this respect are the possibilities that spawning migrations will be blocked by construction or that severe egg and juvenile mortality will result from increased siltation below the construction site. It is imperative that in-stream activities be kept to a minimum at such times.

Spawning of most northern fish species occurs during one of two time periods. Spring spawners, including Arctic grayling, yellow walleye, northern pike, white and longnose suckers, will begin entering streams at approximately breakup (May 15), and will have completed their outward migrations and egg incubation by June 30. Fall spawning species including Arctic and least cisco, inconnu, broad and

humpback whitefish, will normally spawn between September 15 and November 15, although migrations may begin in mid-summer. Although the above dates are generally accurate, each stream must be considered as an individual entity. The period of sensitivity for a given stream fish population will vary with the species and with the geographic location of that stream. Although some tributaries may support significant runs of spring spawning fish, the availability of spawning habitat or low discharge may limit their use by fall spawners.

The general breakup pattern of the Mackenzie River system is such that spring spawning activities can be expected to begin and end approximately two weeks earlier in southern reaches of the system than in the north. Conversely, the fall spawning cycle in the north is generally about two weeks ahead of that to the south.

11.1.3 Safeguards to Fish During Pipeline Routing and Construction.

Prior to actual construction of a pipeline, it will be necessary to analyse proposed stream crossings on an individual basis. Factors such as stream characteristics, amount of suitable habitat and fish species and age composition will govern how stringent safeguards must be to adequately protect the resource. Until such time as specific routes are decided upon, general construction requirements, presently being considered by the Fisheries Service, can be discussed.

PIPELINE ROUTING

1. It is imperative, in our opinion, that streams, whose resources were listed previously as being sensitive to pipeline construction, be avoided where

possible. Should crossings be deemed necessary, special construction techniques, such as suspended crossings, should be considered, to protect the aquatic resources.

2. Assuming that at least a highway and one or more pipelines will be built through the Mackenzie valley, it is recommended that they be routed in a "corridor", and that routes be located as close to each other as safety permits. Siltation resulting from any stream crossing will undoubtedly have some deleterious effect on the fish resource. Unnecessary spacing of crossings will increase the percentage of the resource and the habitat that is affected.

3. No part of a pipeline right-of-way or related facilities, (work camps, staging areas, access roads, etc.) should encroach within 91.4 m (300 ft) of any stream or active flood plain, or any lake greater than 2.5 acres in area or exceeding 3.0 m (10 ft) in depth, except for the purpose of a stream crossing (Fig. 44).

4. No stream crossing should be located within 457.0 m (1500 ft) of the confluence of that stream and the Mackenzie River, or within 457.0 m (1500 ft) of the inlet or outlet of a lake. Areas such as river mouths are extremely important as feeding and rearing areas, and are sensitive to any disturbance or siltation.

PIPELINE CONSTRUCTION

1. Should any stream be crossed by the Mackenzie Highway as well as one or more pipelines, it would be preferable,

Fig. 44. Construction camp on the Blackwater River, N.W.T.

Fig. 45. Cleared approach for a road crossing of a Mackenzie River tributary.

from the Fisheries point of view, if no two crossings were made during the same year. This would permit at least partial recovery of the environment and fish populations before further disruption.

2. There should be no removal or undue disturbance of gravel from stream beds, their active flood plains or from lakes. From a Fisheries viewpoint, the removal of gravel from bars in mid-stream Mackenzie River could be tolerated. However, these areas are frequently used by wildlife, and such activities should have the approval of federal and territorial wildlife agencies.

3. Pipeline right-of-way should not be cleared within 91.4 m (300 ft) of any river or lake until such time as actual construction of the crossing is to begin. Where bank slope exceeds one in three, this uncut zone should extend to the top of that slope. Unnecessary surface disturbance can lead to erosion and silt levels which cannot be tolerated by many fish species (Fig. 45).

4. In the case of a (hot) oil pipeline, the applicant must show that proposed stream crossing construction techniques will enable stabilization of banks occurring naturally as frozen silts.

   A gas pipeline operating at temperatures below freezing must not be constructed so that it interrupts flow through stream bed gravels.

5. Where streams are to be forded, equipment should be restricted to one fording site, and this site should not

exceed 50 ft in width.

6. Construction of stream crossings should be timed to avoid the spawning and egg incubation periods of major fish species inhabiting the stream system. At no time should stream blockages be permitted during biologically critical periods.

7. Temporary stream crossings should only be permitted if they are constructed of non-silt material (Fig. 46). Use of limbed trees in such structures is acceptable to the Fisheries Service. Such crossings must be completely removed prior to breakup, or preferably, immediately upon completion of construction activities. Stream crossings which must remain in place during a fish migratory period must provide easy passage for any fish species inhabiting or utilizing that river system.

8. Actual pipeline crossings should be made at those times considered least sensitive to the fish resource of the system. Stream disturbance should be kept to the minimum necessary for installation of required pipeline facilities. Backfill should consist only of material removed by trenching (Fig. 47). River beds should be reshaped and bank cuts should be stabilized upon installation of the facility.

9. Where, in the opinion of the Fisheries Service, the fish resource appears threatened by loss of significant rearing or spawning habitat, or actual mortality resulting from increased siltation, silt retention techniques such as coffer dams or stream diver-

Fig. 46. A temporary road crossing of a Mackenzie River tributary.

Fig. 47. Wrapping a gas pipeline prior to burial in the trench.

sion, will be required. Contractors may also be requested to delay crossing operations should critical life history stages be considered vulnerable.

ASSOCIATED CONSTRUCTION PROBLEMS

Pollution of any water body with pesticides, domestic or chemical waste materials, cannot be permitted. Work camps, storage facilities, fuel dumps, and associated facilities, should be located away from any water body and adequately protected to avoid water pollution. All equipment, construction material and fuel containers should be back-hauled or removed to approved disposal sites, away from watercourses.

Sport fishing by pipeline personnel, if restricted to a limited area, could exert serious pressure on fish stocks. This is especially true during spawning periods, or where populations are small or are fished domestically. Pending further investigation, it may be necessary to limit or restrict sport fishing on some river systems.

11.1.4 Safeguards to Fish During Northern Pipeline Operation

The greatest post-installation threat of a pipeline to fish resources of the Mackenzie area appears to be increased siltation resulting from stream crossing scouring or erosion. Extreme caution must be taken to ensure that stream bank cuts are suitably stabilized upon installation of the facility. For one year after installation, weekly inspections should be made of each stream crossing for one month after spring breakup, with monthly inspections thereafter until freeze-up.

Quarterly inspections should be made for at least the next two years. Provided adequate stabilization measures are taken when needed, yearly examination of crossings should be sufficient for the remaining life of the line, and should be timed to coincide with periods of peak runoff.

From a Fisheries point of view, there is little potential danger to the aquatic environment from a gas pipeline break. Although some mortality may result from gas saturation, the effects are expected to be restricted to the immediate vicinity of the crossing. Major fish concentrations will probably avoid the area.

The fish resources could be severely threatened by any water pollution resulting from leakage of an oil pipeline. Rearing and spawning areas, benthic organisms and fish would be vulnerable to current carried oil. Automatic shut-off valves are recommended for major river crossings as well as other areas where the fish resource is deemed particularly sensitive. A contingency plan should be required with any pipeline application, and, in the case of an oil pipeline, should include measures to contain an oil spill on watercourses ranging in size from small tributaries to the Mackenzie River. In the case of tributaries, emphasis should be placed on preventing oil from reaching the Mackenzie River. Oil containment and cleanup equipment should be stockpiled at strategic sites along the route. Supervisory personnel must be well trained on cleanup equipment and the procedures to be followed.

Cleanup equipment must be adaptable to cold weather conditions and easily

transportable by air. Use of chemicals which sink or disperse oil spills must not be permitted.

Permanent camp operations and fishing activities of camp personnel will be governed by appropriate federal and territorial government regulations.

11.1.5 Safeguards to Protect the Domestic Fishery Before, During and After Pipeline Construction

Greatest concentrations of domestic fishing effort on the Mackenzie system are found in the Peel River-Mackenzie delta regions (Fig. 48). However, there are usually some locations within a 160-240 km (100-150 mile) radius of each settlement that are fished yearly. Although the majority of fish taken are used for dog feed, much of it is used for human consumption.

Water conditions of the Mackenzie and many of its tributaries are such that successful fishing can be found in a limited number of areas near any community. Recent construction activities have forced some families to move their fishing camps. Nets have been lost or destroyed by increasing river traffic.

It is important that, from both the northern resident's and petroleum industry's point of view, conditions for the fishery are not further jeopardized. Local participation should be stressed in locating pipeline routes, work camps, staging areas, barge landing zones or related facilities, when these approach domestic fishing areas.

Should fishing be conducted for the purpose of feeding construction or

operations personnel, fishing sites should not encroach on any area being actively fished by local residents. No fish may be taken without an appropriate license, issued by the Fisheries Service.

Fig. 48. A domestic fishing camp along the Peel River, N.W.T.

12. NEEDS FOR FURTHER STUDY

12.1 Knowledge Gaps

Results obtained from 1971 and 1972 studies of Mackenzie valley fish resources have provided sufficient estimates for most of the biological parameters being studied. This includes age class composition, length-weight relationships, food habits, age-growth characteristics, and sex ratios of the more abundant species. Baseline data on fish contamination levels was obtained in 1971.

Species composition data for the main stem Mackenzie River and the lower reaches of major tributaries are considered to be complete. Habitat variations in the upper reaches of large tributaries may harbor some species which have gone undetected to date. However, most of these areas are remote from any proposed pipeline routes, and it is unlikely they will be further investigated in any detail.

Aspects of the resource in which knowledge gaps still exist include migration routes and times, locations of spawning grounds, spawning characteristics, and life history details for uncommon species and the juvenile stages of abundant ones. Since susceptibility to environmental change varies with the life history stage of a given species, it is imperative that these gaps be filled prior to construction activities.

12.2 Proposed Additional Studies

With the possible exception of the Aklavik base camp which was only operational during 1972, there are no specific plans to continue the major sample collecting program in 1973.

The tagging program begun in 1972 will be intensified during 1973. The tags used are frequently retained for several years and will provide considerable information concerning fish migration routes and times, while adding credibility to population estimates.

It is anticipated that fish weirs will be built in 1973 on at least one representative tributary in each study area. Weirs will be built at breakup and operate into late fall, permitting monitoring of fish runs entering and leaving these stream systems. Where possible, fish will be tagged as they enter the stream and efforts will be made to locate tagged fish on spawning grounds. Traps will be placed above and below suspected spawning areas to collect emerging fry. Juvenile fish will be fin clipped in an effort to determine their movements within the system.

Periodic helicopter flights will be made to provide logistic support to remote field camps. Limited surveys will be made of major tributaries within base regions, during fish spawning periods.

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15. APPENDIX

Alphabetical list of common names and associated generic names for Mackenzie valley fish species.

Arctic char - Salvelinus alpinus (Linnaeus)
Arctic cisco - Coregonus autumnalis (Pallas)
Arctic grayling - Thymallus arcticus (Pallas)
Arctic lamprey - Lampetra japonica (Martens)
Boreal smelt - Osmerus eperlanus (Linnaeus)
Broad whitefish - Coregonus nasus (Pallas)
Brook stickleback - Culaea inconstans (Kirtland)
Burbot - Lota lota (Linnaeus)
Chum salmon - Oncorhynchus keta (Walbaum)
Dolly Varden - Salvelinus malma (Walbaum)
Emerald shiner - Notropis atherinoides (Rafinesque)
Finescale dace - Pfrille neogaea (Cope)
Flathead chub - Platygobio gracilis (Richardson)
Goldeye - Hiodon alosoides (Rafinesque)
Humpback whitefish - Coregonus clupeaformis (Mitchill)
Inconnu - Stenodus leucichthys nelma (Pallas)
Lake chub - Couesius plumbeus (Agassiz)
Lake cisco - Coregonus artedii (LeSueur)
Lake trout - Salvelinus namaycush (Walbaum)
Least cisco - Coregonus sardinella (Valenciennes)
Longnose dace - Rhinichthys cataractae (Valenciennes)
Longnose sucker - Catostomus catostomus (Forster)
Mountain whitefish - Prosopium williamsoni (Girard)
Ninespine stickleback - Pungitius pungitius (Linnaeus)
Northern pike - Esox lucius (Linnaeus)
Northern redbelly dace - Chrosomus eos (Cope)
Pond smelt - Hypomesus olidus (Pallas)
Round whitefish - Prosopium cylindraceum (Pallas)
Slimy sculpin - Cottus cognatus (Richardson)
Spoonhead sculpin - Cottus ricei (Nelson)
Spotail shiner - Notropis hudsonius (Clinton)
Trout-perch - Percopsis omiscomaycus (Walbaum)
White sucker - Catostomus commersoni (Lacepede)
Yellow walleye - Stizostedion vitreum vitreum (Mitchill)